CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS
AND ENGINEERING

ENGINEERING DESIGN MANUAL
FOR
SUBMERSIBLE LIFT STATIONS

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SECTION 1

INTRODUCTION

SECTION 1
INTRODUCTION

1.1 Purpose

This Manual provides guidance and design criteria for use by Design Engineers developing site-specific drawings for new lift stations. The Design Guideline Drawings for Submersible Lift Stations are to be used with this manual as applicable. The purpose of these documents are to provide facilities that are consistent in quality and arrangement, throughout the City of Houston service areas.

1.2 Coordination with Other Documents

In addition to this manual and the Design Guideline Drawings, the Design Engineer should be familiar with the Design Guidelines for Lift Stations and Force Mains, Equipment Prequalifications, and the City of Houston Standard Technical Specifications for further design criteria or other requirements that may be applicable to a specific project.

1.3 Responsibility of Design Engineer

The overall responsibility of the Contracted Design Engineer is to select the Design Guideline Drawings that are applicable to a specific lift station design and modify the drawings as required. A list of specific design and other requirements that would be the responsibility of the Design Engineer includes, but is not limited to, the following tasks:

1. Obtain from the City direction on which Instrumentation Level to use (I, II or III).

2. Determine if the site will include a control building. A control building should be used for all facilities with Level II or Level III control systems where space is available on-site. Verify the need for or exclusion of, a control building with City of Houston Wastewater operations.

3. Determine which station configuration is required; Preferred, Secured Site or Exposed Site.

4. Perform hydraulic calculations and develop system curves to determine sizes and quantities of the following:

    a. Pumps and motors (identify acceptable models from at least three Prequalified manufacturers)
    b. Discharge piping and valves
    c. Header and force main

5. Determine necessity of and/or sizes for:

   a. Surge relief valve(s) - If surge relief valve is required provide analysis in the Final Engineering Design Report for justification.
   b. Air release valve - An air release valve is required on all lift stations.
   c. Air and vacuum valves

6. Determine piping size for wet well ventilation.

7. Determine size for valve vault ventilation fan(s) and air duct(s), if required.

8. Determine depth of wet well, and wet well volume as it relates to pump controls.

9. If a control building is used, determine the required length and verify or adjust the structural design, as necessary. Review CTE design calculations for the control building to verify adequacy and applicability to the project specific requirements. Provide revised or original calculations as needed to the tailor to the specific project. This is required to allow placing of the design engineer's registration stamp on the Drawings. Include design criteria and assumptions on the Drawings sufficient to obtain building permits.

10. Review CTE design calculations for the wet well top slab (entire structure for 2-pump small lift stations) and valve vault (when used) to verify adequacy and applicability to project specific requirements. Provide revised or original calculations as needed to tailor to the specific project. This is required to allow placing of the design engineer's registration stamp on the Contract Drawings.

11. Complete structural design for wet well walls and base slab. Provide buoyancy calculations.

12. Determine whether caisson, open cut, or both types of construction should be designed and shown on the Contract Drawings based on project specific conditions. The caisson method is often preferred by contractors in the Houston area. Where either method is appropriate, <u>both should be shown as options</u>.

13. Provide a complete listing of the structural design criteria for the lift station and any other related structures. The criteria should include materials, loadings and load combinations, major design assumptions, and design approach. This criteria should be included as an appendix to the Final Engineering Design Report.

14. Obtain 2-year electrical service records from HL&P. Calculate the required storage capacity as defined by 30 TAC.317 and determine measures required to meet power reliability standards.

15. Complete and/or augment conduit and device rating schedules as necessary for specific project requirements. Determine service size from Guideline Drawings.

Obtain available fault current from HL&P and calculate fault ratings. Determine need for and size of power factor correction capacitors.

16. Coordinate with the City's project manager to initiate electrical service/application.

17. Provide all details for site pavement cross section, joints, connection to existing pavement, curbs, sidewalks, etc. Control and/or expansion joints shall be shown located to reduce the potential for cracking.

18. Remove all notes to Design Engineer (shown in Italics) from the Contract Drawings. Provide all information shown as *TBD* or as otherwise instructed in notes to Design Engineer. Revise sheet numbers, title block information, etc. as appropriate for specific project contract drawing package. See Appendix "A", Figure A-5, for a general example.

19. Dimensions on the Guideline Drawings which are modified by "max" or "min", but which need to be selected as a definite dimension by the design engineer should have the appropriate dimension listed without the modifier.

20. Complete additional designer responsibilities as described in this manual.

21. Provide Odor Control facilities if required.

22. Edit and supplement the City of Houston Standard Technical Specifications as needed to apply to the specific project. Delete or indicate as "Not Applicable to this Project" where materials or equipment included in the specifications are not used for the specific project.

23. Comply with the Landscaping requirements of City of Houston Ordinance No. 91-1701.

24. Sign and seal final Contract Documents including Guideline Drawings modified or otherwise included in the Contract Drawings.

25. Provide hydraulic analysis, if required, to justify use of baffle walls in the wet well.

SECTION 2

CIVIL DESIGN CRITERIA

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CIVIL DESIGN CRITERIA

2.1 Description and Design Capacity of Lift Stations

2.1.1 The physical dimensions and range of design capacities of the Lift Stations are shown in the following Table 1.

TABLE 1

LIFT STATION CONFIGURATIONS, PUMPING RANGES DISCHARGE PIPING AND WET WELL SIZES

Pump Station Description	Individual Pump Capacity in GPM		Lift Station - Firm Design Capacity(1) in GPM		Pump Discharge Piping In Inches		Wet Well Diameter
	From	To	From	To	From	To	
2 Pump 100 gpm	-	-	-	100	4"	-	6'-0"
2 Pump	100	300	100	300	4"	-	8'-0"
2 Pump	250	500	250	500	4"	8"	11'-0"
3 Pump	250	2000	500	4000	6"	12"	16'-6"
3 Pump	2000	5300	4000	10,600	12"	20"	21'-0"
4 Pump	500	2500	1500	7500	6"	12"	21'-0"
5 Pump:							
3 large	2000	5300	4000	10,600	12"	20"	25'-0"
2 small (2)	100	1300	_	_	4"	12"	_
6 Pump:							
4 large	3500	5300	10,500	15,900	14"	20"	27'-0"
2 small (2)	100	2000	_	_	4"	12"	_

(1) Firm capacity (largest pump out of service) select range to provide velocity range in force main of 3 to 8 fps.

(2) Small dry weather pumps are not to be considered in lift station firm capacity.

2.1.2 The physical dimensions of the wet well and valve vaults were sized to accommodate the maximum pipe and valve sizes required to pump the maximum range of pumping capacities per pump for each standard station as listed in Table 1.

2.2 Loadings and Clear Opening Dimensions for Hatches and Gratings

2.2.1 Pump and valve vault hatches and valve vault grating shall be designed for 150 psf live loading. FRP grating in standard 48-inch (or less) panel widths shall be used. Provide galvanized steel support beams where required, space so as to avoid interference with access to valves or other mechanical items from above.

2.2.2 The clear opening dimensions of the hatches for each Lift Station are shown on the Design Guideline Drawings.

2.2.3 The Design Engineer shall verify the size and location of the hatch openings based on the selected pump size and manufacturer as well as the selected hatch manufacturer.

2.2.4 The clear opening is area available to lift out pumps or valves when the hatch is open. This area is smaller than the concrete opening in the top slab or the area using the inside dimension of the frame. The reinforcement for the under side of the hatch cover reduces the clear opening of the frame.

2.3 Valve Vault Dimensions and Pump Spacing

The dimensions of the valve vaults associated with each standard station are based on OSHA standard clearances from entrance ladders, piping, valves, and walls or beams.

2.3.1 Ladder Dimensions

Minimum ladder width equals 16 inches. Minimum ladder clearance is as follows:

a. Width:
Center-line of ladder to edge of adjacent wall, valve, piping, or hatch clear opening equals 15 inches.

b. Toe Depth:
Center-line of ladder rungs to wall, grating support, or hatch clear opening equals 7 inches.

c. Body Depth:
Center-line of ladder rungs to wall, valve, piping, or hatch clear opening equals 30 inches.

2.3.2 Valve Vault Head Clearance

Minimum vertical distance from valve vault floor or grate walking surface to bottom of top slab or beam equals 6 feet - 8 inches minimum. Open air valve vaults with grating over them must have enough depth for the air release valve(s) to fit on top of the discharge header and beneath the grating (a minimum vertical distance of 3' - 0").

2.3.3 Valve Vault Pipe Spacing

Minimum spacing between valve vault piping is based on OSHA requirements and 11 inches minimum between hatch openings. Dimensions shown on the Guideline Drawings are based on the following assumptions:

a. Two (2) Pumps with 8" discharge piping:
Minimum spacing of 18 inches plus twice (2X) the smaller center-line to outside edge dimension of the largest recommended check valve, which is 35 inches. Note: The two pump station requires one (1) reverse arm check valve in order to maintain the minimum clearance of 18 inches.

b. Three (3) or four (4) Pumps with 12" discharge piping:
Minimum spacing of 18 inches plus the total width of the largest recommended check valve equals 57 inches.

c. Three (3) or four (4) Pumps with 20" discharge piping:
Minimum spacing of 18 inches plus the larger center-line to outside edge dimension of the largest recommended check valve equals 70.5 inches.

2.3.4 Pump Spacing

Minimum spacing between the wet well pumps is directly related to the center-line spacing of the valve vault discharge piping. **This spacing is to be verified by the design engineer in accordance with selected pump manufacturer's recommendations for proper pump operation.**

2.4 Force Main and Pump Station Size Selection

2.4.1 Force main size and pump station configuration should be based on sound engineering judgement and criteria provided below. Confirm all size and configuration selections with the City of Houston project manager and Wastewater Operations.

2.4.2 The selection of the force main size is based on the velocity of minimum and maximum pumping volumes and the heads generated. The velocities in the force main should be a minimum of 3 fps for minimum flow and a maximum of 8 fps for maximum flow. Force main velocities higher than 6 fps should be checked for possible high and low negative surge pressures during a power failure when all running pumps will stop suddenly. See Section 2.12 "Surge Pressures In A Force Main" for discussion.

2.4.3 A wider range of force main velocities may be considered where there is a high variance between normal dry weather flow and peak wet weather flow. Minimum dry weather discharge velocity should not be less than 2.5 fps, and maximum velocity not greater than 9 fps.

2.4.4 In order to accommodate wet and dry weather flow variations of approximately a maximum 4:1 ratio, the number of pumps selected must be analyzed. In general, an increased number of pumps should be used as the variance between wet and dry weather flows increases.

2.4.5 The total number of pumps should be based on the largest pump as a standby. Therefore, a 4 pump station configuration with 4-1000 gpm pumps will have a design firm station capacity of approximately 3000 gpm.

2.4.6 An example for selection of force main size and a 3 pump or 4 pump station configuration with a maximum design flow of 4.2 mgd is as follows:

<u>Trial No. 1</u> - Use 16 - inch force main
4 pump station = 3 pumps @ 1.4 mgd - min. vel. one pump = 1.55 fps
3 pump station = 2 pumps @ 2.1 mgd - min. vel. one pump = 2.3 fps
Total flow 4.2 mgd max. vel. = **4.65 fps**

<u>Trial No. 2</u> - Use 14 - inch force main
4 pumps station = 3 pumps @ 1.4 mgd - min. vel. one pump = 2.76 fps
3 pumps station = 2 pumps @ 2.1 mgd - min. vel. one pump = 3.2 fps
Total flow 4.2 mgd max. vel. = **8.8 fps**

2.4.7 The selection of the pump station configuration and force main size would be for a 3 pump station with a 14-inch force main. The velocity in the 16-inch force main with 3 pump or a 4 pump station would be too low, and the velocity in the 14-inch force main for either a 3 pump or a 4 pump station @ 8.8 fps would be within recommended criteria for the total flow of 4.2 mgd.

2.5. Pump Selection

2.5.1 The section above establishes the number of pumps and the capacity required to meet total design conditions. Once the number of pumps and the flows have been determined, a system head curve as detailed in the Section 2.10 must be completed. This system head curve will establish the actual flow of the selected pumps and motors operating individually or in combination with the other pumps when pumping against a variable friction head in the force main. The selection of the pump and motor must be based on pump manufacturer's pump curves as shown in Figure 2 and the following considerations relative to efficiency and pumping costs.

2.6 Efficiency and Pumping Cost

2.6.1 If the system head curve is rather flat, consisting of mostly static head, pump selection becomes unimportant in so far as operating power cost is concerned. This can be explained using the following equation:

Cost of pumping 1000 gallons = (TDH x Cents/KWH)/Eff (%) x 3.185

2.6.2 If the station system head (TDH) is assumed to be a constant value which is equal to the static head in this case, then the cost of pumping 1000 gallons will not change whether it is pumped at a rate of 500 gpm for 2.0 minutes or it is pumped at the rate of 1000 gpm for 1.0 minute assuming either pump is equally efficient at the respective operating capacity.

2.6.3 However, if the TDH is due mainly to frictional head loss with little or no static head, the operating power cost of a 1000 gpm pump will be 4 times as high as that of a 500 gpm pump, since the TDH of the pump is directly in proportional to the square of the operating capacity.

2.6.4 Taking the pump efficiency factor at different operating capacity points into consideration the cost of operating a pump at 1000 gpm may be more than 4 times as great. It is therefore important to avoid over sizing a pump when one half of pump size will meet the average requirement.

2.6.5 When two or more pumps operate together for the maximum flow condition care should be taken to insure that each pump will not operate near the shut-off point. For best results pumps should not be operated at less than 50% of the best efficiency point capacity nor be extended to beyond 120% of that capacity. This requirement may be achieved by changing the pump selection, or the force main size, or both.

2.7 Prequalified Pump Manufacturers

2.7.1 Refer to City of Houston Technical Specifications for manufactures prequalified to provide pumps, motors and appurtenances for City of Houston projects. During final design, the design engineer should confirm that at least three prequalified manufacturers can meet the specified conditions.

2.8 Force Main Discharge Manhole

2.8.1 To reduce hydrogen sulfide generation at the discharge end of force main, the discharge flow inside the discharge manhole should be steady, non-turbulent by setting the top of force main pipe to match the average flow depth inside the receiving sewer pipe. A new manhole receiving a force main discharge must be specified and shown on the drawings as a "corrosion resistant manhole".

2.9 Receiving Sewer

2.9.1 The receiving sewer should be designed to handle the maximum pump discharge without surcharge. If two or more pump stations are served by one single sewer pipe, the probable maximum operating capacity of two stations combined should be determined.

2.9.2 Unless the sewer line is long, grade is flat and over sized, there will not be enough storage capacity inside the sewer to smooth out the peaks of two pump stations when they are operated at the same time. Under these conditions the sewer as well as pumps down stream of it, should be designed for the total capacity of two pump stations.

2.10 Example of Construction of System Head and Pump Capacity Curves to Determine Actual Pump Operating Capacities

2.10.1 The selection of the pumps is based on the analysis of system head and pump capacity curves which determine the pumping capacities of the pumps operating alone and with the other pumps as the total dynamic head increases due to additional flow pumped through the force main.

2.10.2 Piping head losses should be calculated in accordance with the Hydraulic Institute Standards in connection with head losses through lift station piping and valves.

2.10.3 The C factors used in calculation of friction head losses should be based on both a C of 120 and C of 140. The pumps should be able to perform between the heads generated between these C factors.

2.10.4 The pump motors should be non-over loading over the entire range of pumping, including the ability to pump into the force main under a flooded wet well condition. The water surface elevation for the flooded condition would be the rim of the lowest adjacent manhole, or the underside of the top slab, which is lower.

2.10.5 Refer to the section on Pump Design Conditions in the Design Guidelines Manual For Lift Stations and Force Mains.

2.10.6 This example of the system head and pump capacity curves is based on the following conditions:

- Force main = single and twin 26-inch force mains
- Length = 15,500 lf
- Total flow ± 20.5 mgd
- Total gpm = 20.50/1440 = 14,236 gpm
- No. of pumps = 4 assuming one pump as standby
- Minimum gpm per pump = 14236 divided by 3 = 4745 gpm
- Select 4 - 5000 gpm pumps

2.10.7 Pump Curves

2.10.8 The pump performance curves represent the volume of liquid that can be pumped with a specified pump and impeller under a range of head conditions. The pump performance curves for the 5000 gpm pump used in this example is shown in Figure 1. It shows the gpm pumped in relation to the various head conditions and best efficiency point with impeller 510 and is tabulated as follows:

GPM	Head
0	124
1500	108
3000	93
4500	78
6000	63
7500	48
9000	33

2.10.9 The above values are plotted in Figure 2 and represent the pump capacity curve for a single pump.

2.10.10 Plotting Multiple Pumping Capacity Curves

2.10.11 The values for multiple pump capacities are also shown in Figure 2. These values are arrived at by constructing the 2nd and 3rd pump capacity curves as a multiple of the Pump No. 1 curve as shown in Figure 3:

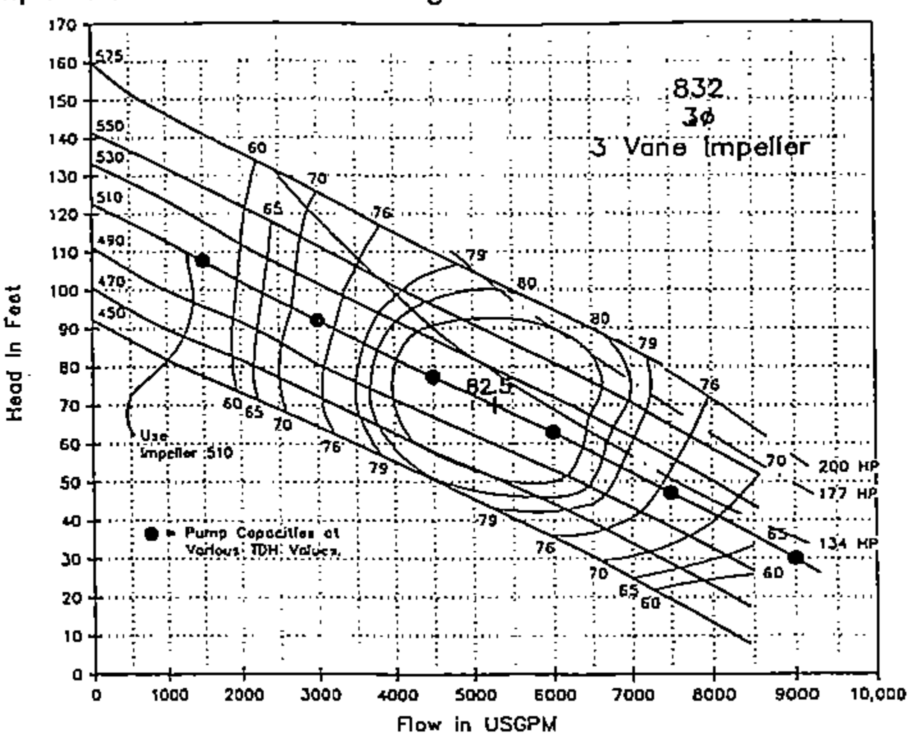


Figure 1
Pump Performance Curve

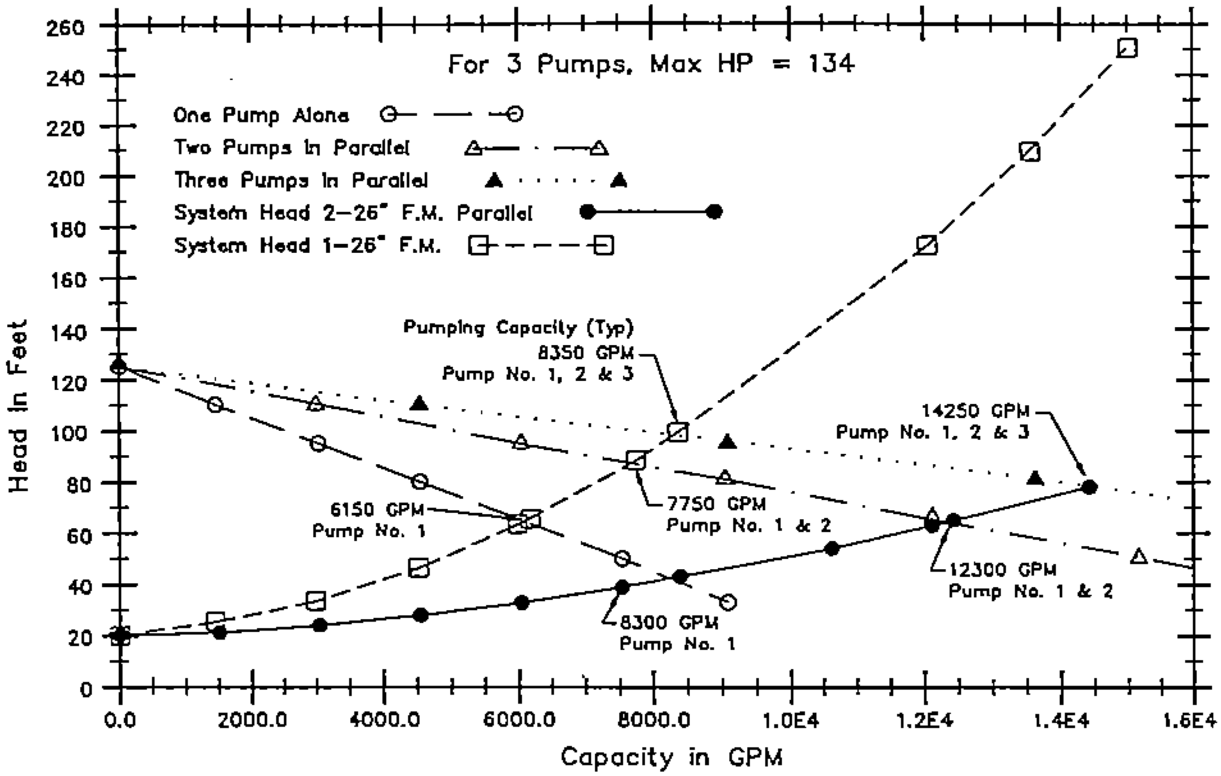


Figure 2
System Head & Pump Capacity Curve

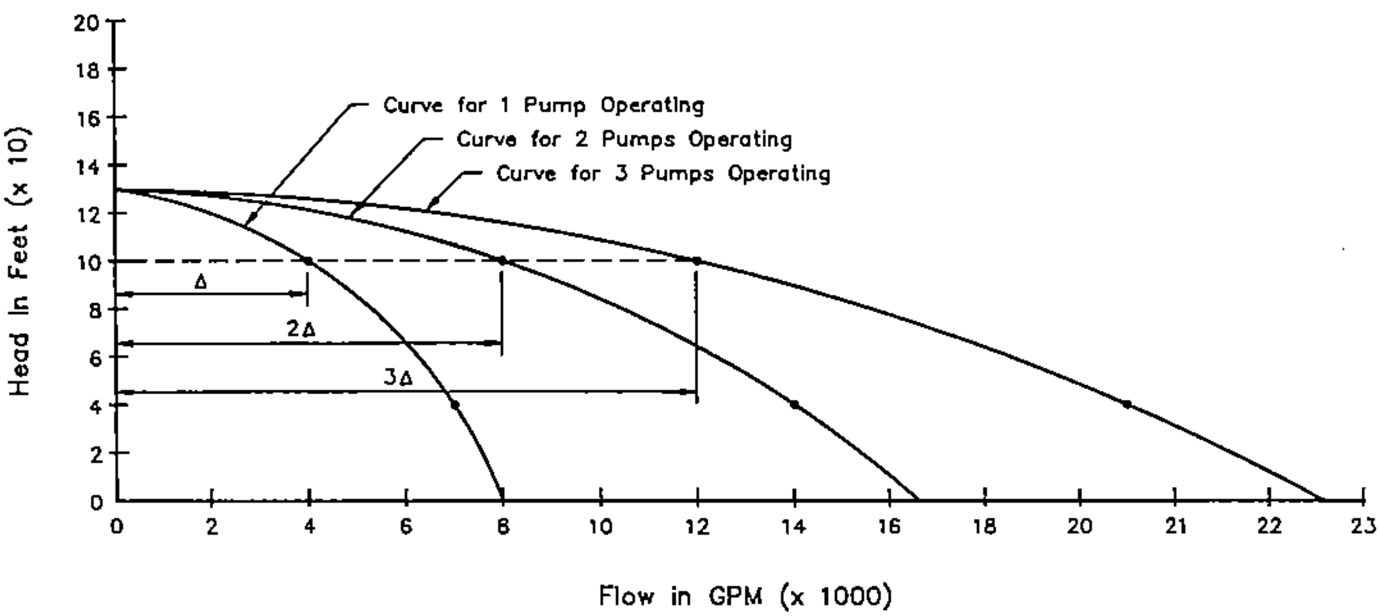


Figure 3
Typical Construction of Multiple Pump Operating Curves

2.10.12 System Head Curve

2.10.13 The system head curve represents the TDH generated by a variety of flows through the proposed or existing force main and includes the static head. As the flows through the force main increase the TDH also increases.

2.10.14 The heads generated through the twin 26-inch force main are as follows:

Flow Through Force Main in GPM	TDH In Feet
0	21
1500	21
3000	24
4500	28
6000	33
7500	39
8300	43
10,500	54
12,000	63
12,300	65
14,250	79

2.10.15 The heads generated through a single 26-inch force main are as follows:

Flow Through Force Main in GPM	TDH In Feet
0	21
1500	24
3000	32
4500	45
6000	63
7500	65
8300	88
10,500	98
12,000	172
12,300	209
14,250	250

2.10.16 The values of the twin and single 26-inch force main are plotted on the system head and pump capacity curves as shown in Figure 2, and represents the system head curves for the single 26-inch force main and for the twin 26-inch force mains.

2.10.17 Determine System Pumping Capacities For Multiple Pumps

2.10.18 The actual pumping capacities are determined by the intersection of the system head curves for single and twin 26-inch force mains with the pump capacity curves as shown in Figure 2.

2.10.19 The system pump capacities based on pumping into the single or twin 26-inch force main are shown as follows:

Pump Capacities Using Single 26-inch Force Main

No. of Pumps	Capacity Increase GPM	Total Pumping Capacity in GPM	TDH
1	6150	6150	65
2	1600	7750	88
3	600	8350	98

Pump Capacities Using Twin 26-inch Force Main

No. of Pumps	Capacity Increase GPM	Total Pumping Capacity in GPM	TDH
1	8300	8300	43
2	4000	12300	65
3	1950	14250	79

2.10.20 The above values illustrate the wide range of the 5000 gpm pump over the range of system head conditions. A single pump ranges from 6150 to 8300 gpm. The maximum required total pumping rate of 20.5 mgd or 14,236 gpm is achieved by three pumps pumping into the twin 26-inch force main @ a maximum rate of 14250 gpm.

2.11 Wet Well Design

2.11.1 Minimum Wet Well Volume

2.11.2 The minimum required volume of wet well storage occurs when the flow into the wet well is one half the maximum inflow. In order to calculate this volume a minimum cycle time between starts of 6 minutes should be used for motors less than 50 H.P. so that the motor will have a maximum of 10 starts per hour. The cycle time for pump motor horse power between 50 and 100 H.P. should be 10 minutes and the cycle time for pump motors over 100 H.P. should be 15 minutes. The formula for minimum wet well volume is:

$$V = (T_{min} \times QP) / (4 \times 7.5 \text{ gal/cf})$$

Where: Tmin = minimum cycle time in minutes
QP = pump capacity in gpm
V = volume in cubic feet

2.11.3 An example calculation to determine the minimum wet well volume is provided below. This example illustrates the wet well volume requirements for a 4 pump station using the following parameters:

- Max flow = 2370 gpm or 3.41 mgd
- No. of pumps = 4
- Pump capacities = 4 @ 800 gpm
- Cycle time = 6 minutes
- 12 inch force main, 1600 feet long
- Wet well surface area = 120 sf

2.11.4 The first step would be to develop a system head curve which will show the actual pumping capacities based on the variable friction heads generated in the force main as each pump is turned on. Based on the system head curve pump no. 1 would pump 1080 gpm, pump no. 1 and 2 would pump 1980 gpm, and pump no. 1, 2 and 3 would pump 2370 gpm. Pump No. 4 is a standby.

2.11.5 The wet well volume and corresponding pumping range in feet to accommodate the 6 minute cycle for each pump as they are turned on is:

For Pump 1, $V\text{-}1 = \dfrac{6.0 \text{ min.} \times 1080 \text{ gpm}}{7.48 \text{ gpm/cf} \times 4} = 217\text{cf},\ H_1 = 1.8'$

For Pump 2, $V\text{-}2 = \dfrac{6.0 \text{ min.} \times (1980\text{-}1080)}{7.48 \text{ gpm/cf} \times 4} = 180\text{cf},\ H_2 = 1.5'$

For Pump 3, $V\text{-}3 = \dfrac{6.0 \text{ min.} \times (2370\text{-}1980)}{7.48 \text{ gpm/cf} \times 4} = 78\text{cf},\ H_3 = 0.7'$

Total Wet Well Volume = 475cf, Total H = ± 4'

2.11.6 The following Table 2 shows the water levels (WL), and the heights (H) that water level rises or falls between pump stop and start, and indicates the pump status (either off or on).

Table 2

PUMP CONTROL SCHEDULE EXAMPLE

		Rising Water Level		Falling Water Level	
WL Elev.	Δ H	Action	Pump Station	Action	Pump Status
4.00		P-3 on	P-1, P-2 & P-3 on		P1, P-2 & P-3 on
3.30	0.7	P-2 on	P-1 & P-2 on	P-1 off	P-2 & P-3 on
1.80	1.5	P-1 on	P-1 on	P-2 off	P-2 on
0.00	1.8		All Stop	P-3 off	All Stop

2.11.7 A typical section showing the start and stop control levels in a wet well is shown in Figure 4 on the following page.

2.11.8 Determine the required size for the ports in the baffle wall. The dimensions of the ports should be stated on the structural drawings. Size ports such that the velocity through all ports at firm station capacity is greater than 4.5 fps and less than 6.5 fps.

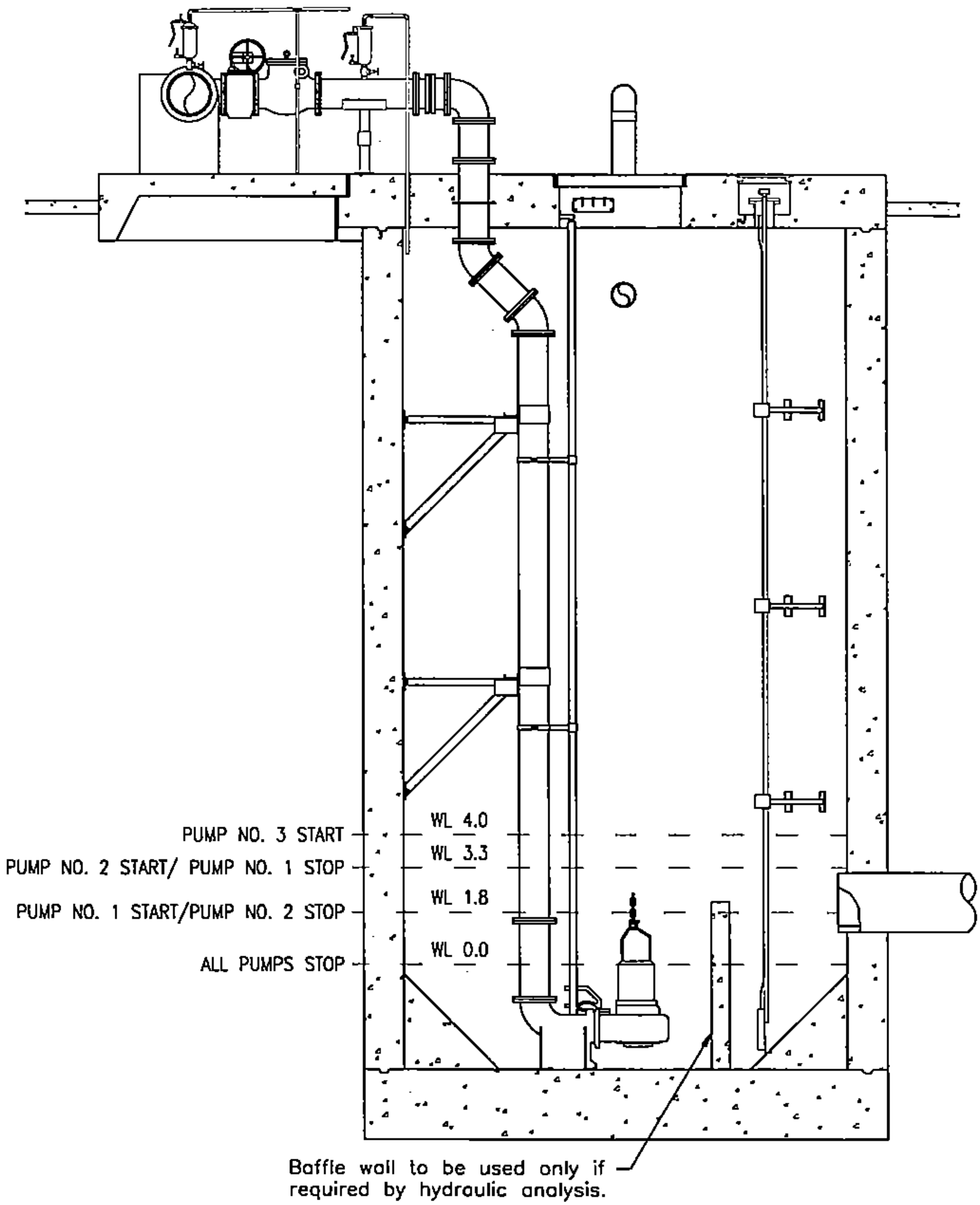


Figure 4
Typical Wet Well Elevation Showing Pump Control Levels

2.12 Surge Pressure in a Force Main

Surge pressure or "Water Hammer" in a force main is created by any change from a steady state flow condition, and may range from only slight pressure and/or velocity changes to sufficiently high vacuum or pressure conditions which may cause the collapse or rupture of the pipeline, or cause damage to pumps and/or valves. Water hammer is typically caused by the opening, closing or regulating of valves; or by the starting and/or stopping of pumps. The magnitude of the surge pressure created is a function of the following:

1. A change in the velocity of flow.
2. The density of the fluid.
3. The speed of the pressure wave within the fluid and piping system.

2.12.1 Velocity of Pressure Wave

The speed or velocity of the pressure wave is a function of the following factors:

1. Pipeline material (steel, cast iron, ductile iron, plastic, etc.)
2. Pipeline wall thickness
3. Pipeline diameter
4. The specific gravity and bulk modulus of the fluid being pumped.

The relationship of these various factors is expressed in the following equation:

$$a = \sqrt{1 \div \frac{w}{g} \times \left(\frac{1}{K} + \frac{D}{e} \times \frac{C_1}{E^1} \right)}$$

<u>Where</u>: a = Pressure wave speed, expressed in feet per second (ft/sec)

D/e = A dimensionless ratio of the pipeline diameter to its wall thickness.

E^1 = Young's Modulus of Elasticity for the pipeline material, expressed in pounds per square foot (lb/sf) and which for steel pipe is 4,390,000,000 lb/sf; for cast iron pipe is 1,730,000,000 lb/sf; and for ductile iron pipe is 3,456,000,000 lb/sf.

K = Bulk Modulus of water, expressed in lb/sf and which is 43,200,000 lb/sf at 20° C.

w/g = Mass density of water, expressed in slugs per cubic foot which is 62.4/32.2 = 1.938 slugs/cf.

C_1 = Coefficient of pipe support condition, which is dependent on Poisson's ratio (mu), which for most pipe materials the accepted mu = 0.3.

Note: The usual range of C_1 is 0.85 to 1.25 and is determined as follows:

C_1 for a pipe anchored at one end only, while the other end is free = 5/4 - mu = 0.95.

C_1 for a pipe anchored at both ends = 1 - $(mu)^2$ = 0.91.

C_1 for a pipe anchored at both ends with an expansion joint between anchors = $1 - \frac{mu}{2} = 0.85$.

Also, the pressure wave speed in water is usually in the range of 3000 to 4000 ft/sec, and using a value of 3500 ft/sec is generally sufficient for approximations.

2.12.2 Approximate Wave Speeds Examples Pipes

The following Tables 3, 4 and 5 show approximate wave speeds in various types of pipe based on the Modulus of Elasticity (E) as shown and Poisson's ratio (Mu) at the value of 0.3.

TABLE 3

WAVE SPEED IN STEEL AND CAST IRON PIPES

	Wave Speed in f/sec.	
D/e ratio	Steel Pipe $E=30 \times 10^6$psi	Cast Iron Pipe $E=12 \times 10^6$psi
25	4250	3750
50	3900	3250
75	3600	2900
100	3400	2600
150	3000	2250
200	2750	2000

TABLE 4

WAVE SPEED IN HOBAS PIPES

(Wave Speed in f/sec.)

D/e ratio	Class 50 psi $E=0.5 \times 10^6$psi	Class 100 psi $E=1.2 \times 10^6$psi	Class 250 psi $E=2.8 \times 10^6$psi
12	1720	2450	3200
16	1510	2200	2950
20	1370	2000	2750
25	1230	1830	2550
50	890	1350	1950
75	730	1110	1640
100	630	970	1440

TABLE 5

WAVE SPEEDS IN OTHER PLASTIC PIPES

(Wave Speed in f/sec.)

D/e ratio	H.D. Polyethylene Pipe $E=0.113 \times 10^6$psi	Other Plastic Pipe $E=1.20 \times 10^6$psi
12	860	1130
16	750	990
20	670	890
25	603	800
50	428	570
75	350	460
100	300	400

2.12.3 Surge Pressure - Sudden Flow Stoppage

The magnitude of surge pressure per unit change in the velocity of flow is expressed by the following equation, for the sudden or instantaneous stoppage of flow:

$$h_w = av \div g$$

<u>Where:</u> h_w = pressure rise expressed in feet
a = pressure wave speed expressed in ft/sec
v = flow velocity of the pumped fluid in ft/sec
$g = 32.2$ ft/sec^2

Thus, if a liquid is flowing at a velocity of 10 ft/sec through a pipeline and is brought to a sudden stop, the increase in pressure, or surge pressure, using a pressure wave speed of 3500 ft/sec is determined as follows:

$$h_w = av \div g \quad = 3500 \text{ ft/sec} \times 10 \text{ ft/sec} \div 32.2 \text{ ft/sec}^2$$

$$= 35{,}000 \text{ ft}^2/\text{sec}^2 \div 32.2 \text{ ft/sec}^2 = 1087 \text{ ft}$$

$$1087 \text{ ft} \div 2.31 \text{ ft/psi} = 470.56 \text{ psi}$$

2.12.4 Surge Pressure - Change in Flow

If the velocity of flow within the force main is changed, but not completely stopped, the surge pressure rise is expressed by the following equation:

$$h_w = \frac{a}{g}(v_1 - v_2)$$

<u>Where:</u> v_1 = original steady flow velocity expressed in ft/sec
v_2 = final steady flow velocity expressed in ft/sec

Thus, if a liquid is flowing at a velocity of 8 ft/sec while being pumped by two pumps, then one pump is stopped resulting in a flow velocity of 4 ft/sec, the increase in pressure or surge pressure, using a pressure wave speed of 3500 ft/sec is determined as follows:

$$h_w = \frac{a}{g}(v_1 - v_2) = \frac{3500 \text{ ft/sec}}{32.2 \text{ft/sec}^2} (8 \text{ft/sec} - 4 \text{ ft/sec})$$

$$= 108.7 \text{ 1/sec} (4 \text{ ft/sec}) = 434.8 \text{ ft}$$

$$434.8 \text{ ft} \div 2.31 \text{ ft/psi} = 188 \text{ psi} \pm$$

It should be noted that as a "Rule of Thumb" the above equations, $h_w = av \div g$ and $h_w = a/g\ (v_1 - v_2)$, will yield a surge pressure of approximately 100 ft of water (43.3 psi) per each 1 fps change in velocity.

2.13 Comparison: Surge Analysis by Computer Program

It should be noted that the above equation represents the maximum surge pressure possible for a given situation. The equation works well for simple one pipe situations where near instantaneous flow velocity changes occur. In more complex situations, such as pumping stations or pipe networks, the use of this equation may tend to predict excessive pressures. These predictions then often lead to over design of pumping stations, pipelines, etc., which unnecessarily drives up project costs.

A more detailed analysis using a computer model will often provide a lesser, but more accurate, design pressure and also provide insight into other potential problems such as minimum and negative pressures predicted as well as potential cavitation locations within a pipeline. The more accurate design pressures may allow the designer to specify less costly materials while still maintaining an appropriate safety factor. In complex situations, the cost of a thorough computer analysis is usually justified by total project savings. An example comparing the two methods is given below:

Using the data for Example No. 1 (Section 2.15), the surge pressures predicted by the above equation is 294 psi.

By constructing a simple computer model, the predicted pressures drop to 230 psi.

By constructing a somewhat more complex computer model, the predicted pressures drop further to 137 psi.

2.14 Surge Pressure Considerations:

2.14.1 Pipeline Length

For pipelines of infinite length, surge pressures resulting from variations in the velocity of flow through the pipeline are not affected in magnitude by the rate at which the velocity of flow is changed. However, this effect is not true in pipelines of finite length. This difference is significant in surge pressure phenomena in actual pipelines.

2.14.2 Wave Reflection

In actual pipeline situations, surge pressure problems can become somewhat more complex because the end of the pipeline institutes the mechanism of wave reflection. That is, when the pressure wave reaches the end of the force main, it reverses direction and a wave of increased pressure travels back to the pumps or valve, where reversal of the pressure wave takes place again and a second pressure wave of reduced magnitude travels the length of the pipeline. This is repeated over and over until steady state is reached.

2.14.3 Pipeline Friction

Pipeline friction helps to decelerate the pressure wave velocity, thus each time the pressure wave travels along the length of the pipeline in either direction, its velocity in the pipeline decreases. The change in velocity of the pressure wave is expressed by the following equation: $\Delta v = Gh/a$, where, h is the difference in head (pressure) at the two ends of the force main plus the friction head, at the average velocity of the pressure wave, during the passage of the wave.

2.14.4 Sudden Change in Flow Conditions

A change in flow conditions within a force main is considered to be "sudden" if the change is completed within the time period required for the surge pressure wave to travel the length of the force main, be reflected, and return to the point of origin. This time period for the surge pressure wave to make a round trip is referred to as the "critical period" of the force main and is expressed by the equation $t = 2L/a$, where L = the distance between the point of flow change, i.e. pumps or valve, and the point of wave reflection. The maximum surge pressure occurs at the point of velocity change, regardless of the rate of change in velocity.

2.14.5 Gradual Change in Flow Conditions

A change in flow conditions with a force main is considered to be "gradual" if the change is completed in a period of time which is greater than the "critical period". This scenario may be considered as a series of flow velocity changes, each produced in a time equal to or less than 2L/a. For "n" increments of change in velocity within the initial period of 2L/a:

1. The greatest incremental pressure change will result from the largest incremental change in velocity.

2. The total pressure change during the first interval of 2L/a will be the sum of the "n" incremental changes in pressure which occurred during the initial interval.

The maximum surge pressure change may, however, occur after the first 2L/a interval and should be determined from an accurate analysis of the direct and reflected impulses as performed by a graphical or computer model analysis.

2.14.6 Potential Severity of Surge Pressure

In assessing the potential severity of a possible surge pressure situation, it is necessary to determine whether the change in flow conditions are to be considered as "sudden" or "gradual".

As an example, if the length of force main being considered is 1500 feet, the wave velocity is assumed to be 3500 ft/sec, the "critical period" is determined to be 2L/a = 2 x 1500 feet ÷ 3500 ft/sec = 0.9 seconds. Since it is practically impossible to intentionally produce a significant change in velocity within 1 second or less, in pipeline sizes typically encountered, the "sudden" change case most likely will not occur, and therefore maximum surge pressures are not likely to occur. This is very characteristic of "short" force mains and with the exception of possible slamming of check valves, these force mains are seldom of concern, and would not require any surge relief valves or other devices.

On the other hand, as an example, if the length of force main being considered is say 20,000 feet, and the wave velocity is still assumed to be 3500 ft/sec, then the "critical period" is determined to be 2L/a = 2 x 20,000 ft ÷ 3500 ft/sec = 11.4 seconds. Under this scenario, a substantial change in the flow velocity can be achieved within this time period and is likely to be of serious concern.

2.14.7 Probable Effects of Surge Pressure

The following brief discussion is presented to assist in ascertaining the probable effects of surge pressure by classifying the physical characteristics of the force main. Identification of the initial cause of the change in flow from the steady state must be made. The three most frequently encountered probable causes are:

1. The opening/closing of a valve.
2. The starting/stopping of a pump.
3. The failure of the force main.

Typically, the manual or automatic operation of valves cannot cause a "sudden" change in the flow conditions and cause a surge pressure of concern. Pumping systems, however, are more often of a more serious concern and typically have two types of problems associated with them:

1. The starting/stopping of the pumps under normal operating conditions.
2. The pump operation under power failure conditions.

Under normal operating conditions the change in flow conditions are typically controlled by valves in the pump discharge line, and may be considered as a control valve condition, which would not cause a "sudden" change in the flow condition or cause a surge pressure of concern.

In a power failure condition the pumps may initiate and cause a surge pressure. If the probable effect of surge pressure is serious, according to the criteria presented above, a detailed analysis by experts is recommended.

Additionally, if a pump discharge valve closes "suddenly", before the forward movement of the water column stops, cavitation of the water column may occur.

Cavitation may also occur at high points in the force main during the initial phases of pressure loss in the system. Vapor cavities formed under these conditions are typically closed with violent impact upon reversal of the flow and can result in extremely high surge pressures. The analysis of surge pressures associated with cavitation require a detailed computer analysis.

Likewise, a failure of the force main can cause complex surge pressures the analysis of which would best be accomplished by performing a detailed computer analysis by an expert in the field.

2.14.8 Classification of Pumping Systems

Table 6 is a simple classification of pumping systems into two categories "A" and "B". Surge problems occurring under category "A" situations are typically of minor concern and usually occur with great frequency in actual practice. The severity of the surge problems associated with the category "A" situations may be determined from the check list presented as Table 7.

TABLE 6

CLASSIFICATION OF FORCE MAINS IN PUMPING SYSTEMS

1.	**Type of System**	**A**	**B**
	A. Single pipeline of uniform size	X	
	B. Single pipeline of more than one size		X
	C. Two or more parallel lines		X
	D. Single or parallel system connected to a distribution grid		X
2.	**Profile of System**		
	A. Relatively flat or gradual ascending slope	X	
	B. Steep slope (length less than 20 times the pump head)		X
	C. Intermediate high Points		X
	D. Intermediate pumps or tanks		X
3.	**Pump Suction conditions**		
	A. Suction direct from suction well	X	
	B. Suction line in which the critical period (2L/a) is 1 second or less	X	
	C. Suction line in which the critical period (2L/a) is greater than 1 second		X

If the pumping system to be analyzed contains any items listed under category "B", it is recommended that the system be referred to experts for analysis.

If the pumping system to be analyzed contains only items listed under category "A", proceed to Table 7.

TABLE 7

CHECK LIST FOR FORCE MAINS OF CATEGORY "A" ITEM ONLY

		YES	NO
1.	Is "Critical Period" greater than 1.5 seconds?		
2.	Is the maximum flow velocity in the force main greater than 4.0 ft/sec?		
3.	Will any check valve in the force main close in less than the "critical period" (2L/a)?		
4.	Will the pump or motor be damaged if allowed to run backwards, up to full speed?		
5.	Is the factor of safety for the force main less than 3.5 under normal operating conditions?		
6.	Are there any automatic quick closing valves in the force main set to open/close in less than 5 seconds?		
7.	Are there any automatic valves within the pumping system that become inoperative due to loss of pumping system pressure?		
8.	Will the pump(s) be tripped off prior to full closure of the discharge valve?		
9.	Will the pump(s) be started with the discharge valve open?		

If the answer to **<u>any one</u>** of the above questions 1 thru 6 is **yes**, there is reason for concern regarding surge pressures. If **<u>two or more</u>** of the above questions 1 thru 9 are answered **yes**, the situation is likely to be serious and the degree of severity will be in proportion to the number of **yes** answers.

2.15 Examples of Surge Pressure in a Force Main

The following are examples to illustrate the use of Tables 6 and 7 (Section 2.14.8) as well as the various equations presented previously, which are intended to assist in determining the probable effects of surge pressures.

2.15.1 EXAMPLE NO. 1

2.15.1.1 Design Data:

1. Pumps: Three (3) identical units (1 standby),
   Rated Flow (each) = 5000 gpm (7.2 mgd).
   Station Design Capacity = 10,000 gpm (14.4 mgd).
   Assumed Pump Rundown Time Under Full Head = 1.5 Seconds.
   Rated Discharge Head = 78 Feet.

2. Force Main: 26-inch Diameter Steel Pipe, Length = 8000 Feet.

3. Valves: 24-inch C.I. Plug Valves (suction side).
   18-inch C.I. Plug Valves (discharge side).
   18-inch Swing Check Valves (discharge side).

4. Pump Suction: Suction directly from wet well through 24-inch diameter suction pipe (2L/a) = 2 x 15/3500) = < 1 second

2.15.1.2 Data for Surge Pressure Analysis:

1. Steady State Conditions:

   a. Flow = 14.4 mgd = 22.3 cfs
   b. Velocity = 6.24 ft/sec
   c. Total Head = 78 feet
   d. Static Head = 5 feet

2. Critical Period:

   a. Wave Velocity, a = 3500 ft/sec (assumed)
   b. 2L/a = 2 x 8000/3500 = 4.5 sec

3. Force Main Profile:

   a. No Intermediate High Points
   b. Relative Slope = L/ΔH = 8000/80 = 100> 20

4. Cause of initial surge pressure = power failure.

5. Sudden or gradual velocity change = sudden, since the assumed pump run down time of 1.5 seconds is less than the critical period of 4.5 seconds.

6. Maximum Surge Pressure Anticipated:

$$\begin{aligned} h_w = av \div g &= 3500 \text{ ft/sec} \times 6.24 \text{ ft/sec} \div 32.2 \text{ft/sec}^2 \\ &= 21{,}840 \text{ ft}^2/\text{sec}^2 \div 32.2 \text{ ft/sec}^2 \\ &= 678.3 \text{ feet (294 psi)} \end{aligned}$$

2.15.1.3 Classification of Force Main:

Using Table 6, all applicable items fall under the "A" category, therefore, proceed to Table 7.

2.15.1.4 Force Main Check List Items:

Items receiving **"yes"** answers:

No. 1. Critical period greater than 1.5 seconds.

No. 2. Flow velocity greater than 4.0 ft/seconds.

Items receiving **"questionable"** answers:

No. 3. Closure of check valve less than the critical period (4.5 seconds)

No. 4. Will pump and/or motor be damaged by reverse rotation.

This example indicates that there is a potentially serious surge pressure condition that could occur due to the possible sudden closure of the check valve(s). Additionally, it indicates that there may be a concern regarding the potential damage that could be caused by reverse rotation of the pump and/or motor along with a possible need to review this condition with the manufacturer.

2.15.2 EXAMPLE NO. 2

2.15.2.1 Design Data: Same as for Example No. 1

2.15.2.2 Data For Surge Pressure Analysis:

1. Steady State Conditions:

   a. Flow Q_1 = 14.4 mgd = 22.3 cfs
   Q_2 = 7.2 mgd = 11.1 cfs

b. Velocity $v_1 = 6.24$ ft/sec
$v_2 = 3.12$ ft/sec

c. Total Head = 78 feet

d. Static Head = 5 feet

2. Critical Period: Same as for Example No. 1

3. Force Main Profile: Same as for Example No. 1

4. Cause of initial surge pressure = Loss of power to one of the two pumps running.

5. Sudden or gradual velocity change = sudden, since the assumed pump rundown time of 1.5 seconds is less than the critical period of 4.5 seconds.

6. Maximum Surge Pressure Anticipated:

$$h_w = \frac{a}{g}(v_1 - v_2) = \frac{3500 \text{ ft/sec}}{32.2 \text{ ft/sec}^2}(6.24 \text{ ft/sec} - 3.12 \text{ ft/sec})$$

$$= 108.7 \text{ 1/sec } (3.12 \text{ ft/sec})$$

$$= 339 \text{ feet } (147 \text{ psi})$$

2.15.2.3 Classification of Force Main:

Using Table 6, all applicable items fall under the "A" category, therefore, proceed to Table 7.

2.15.2.4 Force Main Check List Items:

Items receiving **"yes"** answers:

No. 1. Critical period greater than 1.5 seconds.

No. 2. Flow velocity greater than 4.0 ft/sec initially.

Items receiving **"questionable"** answers:

No. 3. Closure of check valve in less than the critical period of 4.5 seconds.

No. 4. Will pump or motor be damaged by reverse rotation.

2.15.2.5 This example indicates that there is a potentially serious surge pressure condition that could occur due to the possible sudden closure of the check valve(s). Additionally it indicates that the severity of the surge pressure will be less than if both pumps were suddenly shut down. It also indicates that there may be a concern regarding the potential damage that could be caused by reverse rotation of the pump and/or motor along with a possible need to review this condition with the manufacturer.

2.15.3 EXAMPLE NO. 3

2.15.3.1 Design Data:

1. Pumps: Two (2) identical units (1 standby)
   Rated Flow (each) = 3000 gpm (4.3 mgd)
   Station Design Capacity = 3000 gpm (4.3 mgd)
   Assumed Pump Rundown Time under full head = 1.5 seconds.
   Rated Discharge Head = 55 feet

2. Force Main: 26-inch diameter steel pipe
   Length = 6500 feet

3. Valves: 16-inch C.I. plug valves, manually operated on suction and discharge of pumps.

4. Pump Suction:

   Takes suction directly from wet well through 16-inch diameter suction pipe (2L/a) = (2 x 15/3500) = <1 second.

2.15.3.2 Data For Surge Pressure Analysis:

1. Steady State Conditions:

   a. Flow = 4.3 mgd = 6.65 cfs

   b. Velocity = 1.87 ft/sec

   c. Total Head = 55 feet

   d. Static Head = 5 feet

2. Critical Period:

   a. Wave Velocity, a = 3500 ft/sec (assumed)

   b. 2L/a = 2 x 6500/3500 = 3.7 sec

3. Force Main Profile:

   a. No intermediate high points.

   b. Relative slope = $L/\Delta H$ = 6500/55 = 118>20

4. Cause of initial surge pressure = Power failure.

5. Sudden or gradual velocity change = Sudden, since the assumed pump rundown time of 1.5 seconds is less than the critical period of 3.7 seconds.

6. Maximum Surge Pressure Anticipated:

$$\begin{aligned} h_w &= av \div g = 3500 \text{ ft/sec} \times 1.87 \text{ ft/sec} \div 32.2 \text{ ft/sec}^2 \\ &= 6545 \text{ ft}^2/\text{sec}^2 \div 32.2 \text{ ft/sec}^2 \\ &= 203.3 \text{ feet (88 psi)} \end{aligned}$$

2.15.3.3 Classification of Force Main:

Using Table 6, all applicable items fall under the "A" category, therefore proceed to Table 7.

2.15.3.4 Force Main Check List Items:

Items receiving **"yes"** answers: No. 1 Critical period greater than 1.5 seconds.

Items receiving **"questionable"** answers: No. 4 Will pump and/or motor be damaged by reverse rotation.

2.15.3.5 This example indicates that there is a potentially minor surge pressure condition that could occur due to the shut down of the pump on a loss of power. It also indicates that there may be a concern regarding the potential damage that could be caused by reverse rotation of the pump and/or motor along with a possible need to review this condition with the manufacturer.

2.16 Surge Relief Valves

Surge relief valves are typically installed at pump stations to protect the pumps, piping, valves and other equipment from potential damage from surge pressures. Surge relief valves should be sized to release the excess surge flows through the valve either on the basis of system flow or so that the inlet pressure measured at the relief valve will be lower than the lowest pressure rating of the pumping equipment.

All manufacturers of surge relief valves have a value size selection chart in their catalog for the purpose of selecting the proper sized valve for the force main system, or portion thereof, to be protected. Figure 5 is an example of a valve size selection

chart which is reproduced from the GA Industries, Inc. Catalog No. GA-2000.
Surge relief valves are to be located downstream of the pump control valve/check valve or on the main discharge header as close to the pump(s) as practical. Surge relief valves typically discharge back into the wet well.

Consideration should be given to providing two or more smaller sized valves having a total combined relieving capacity equal to or greater than a single larger sized valve, especially when there is more than one pump discharging into a common header. A surge relief valve may be utilized on each pump discharge line or several valves may be provided on the common discharge header.

When several valves are provided it is advisable that each valve's pressure setting be slightly higher than the adjacent valve allowing the valves to open in sequence instead of all at once. It should be noted that all surge relief valves are field adjustable and their relief pressure setting range is determined when the valves are ordered from the manufacturer.

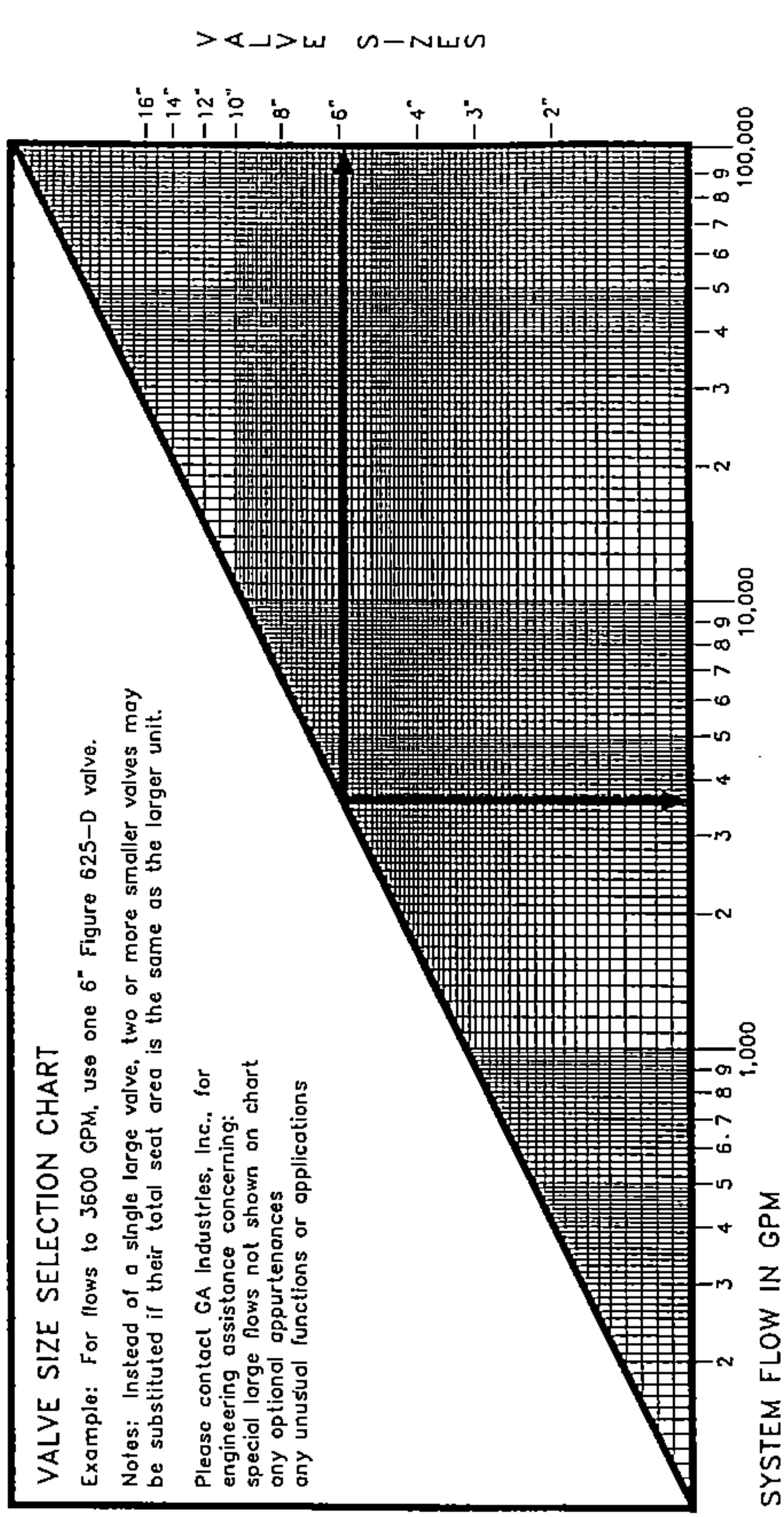


Figure 5
Example of Surge Relief Valve Size Selection Chart

2.17 Pipeline Design

2.17.1 Refer to the latest edition of the City of Houston "Design Guidelines for Lift Station and Force Mains" for additional design criteria.

2.17.2 Pipeline velocity higher than 6 fps should be checked for possible high and low negative surge pressures during a power failure when all running pumps stop suddenly.

2.17.3 The length of the pipeline should be kept as short as practical to decrease the detention time and odor generation.

2.17.4 The vertical alignment of pipeline should avoid a steep slope of pipe near the pump station followed by a long stretch of flat grade. This type of alignment is often the cause of column separation. See Figure 6. A rising pipe followed by a falling one will require an air vent to be installed at the summit.

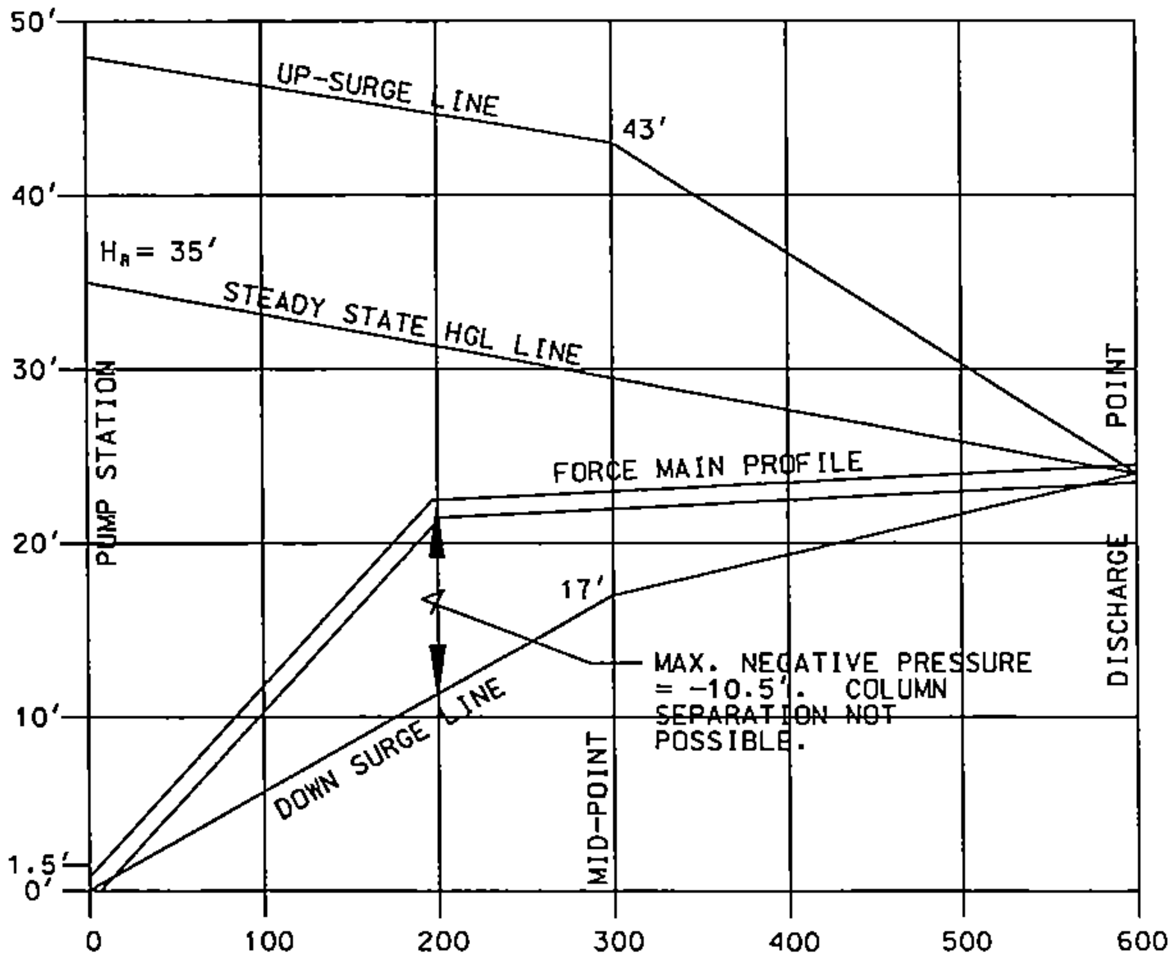


Figure 6
Example of Column Separation Determination

2.17.5 Pipeline passing through peaks and valleys require vents at the high point and drains in the low point. Such pipe profiles should be checked very carefully for air entrapment and air release. Either one could cause high surge pressure due to improper selection of air valve sizing. Also, the static head of a pipeline having ups and downs with entrained air pockets should be carefully checked. Under certain conditions the static head of each water column should be added cumulatively, even through they appeared to be canceling each other. See Figure 7.

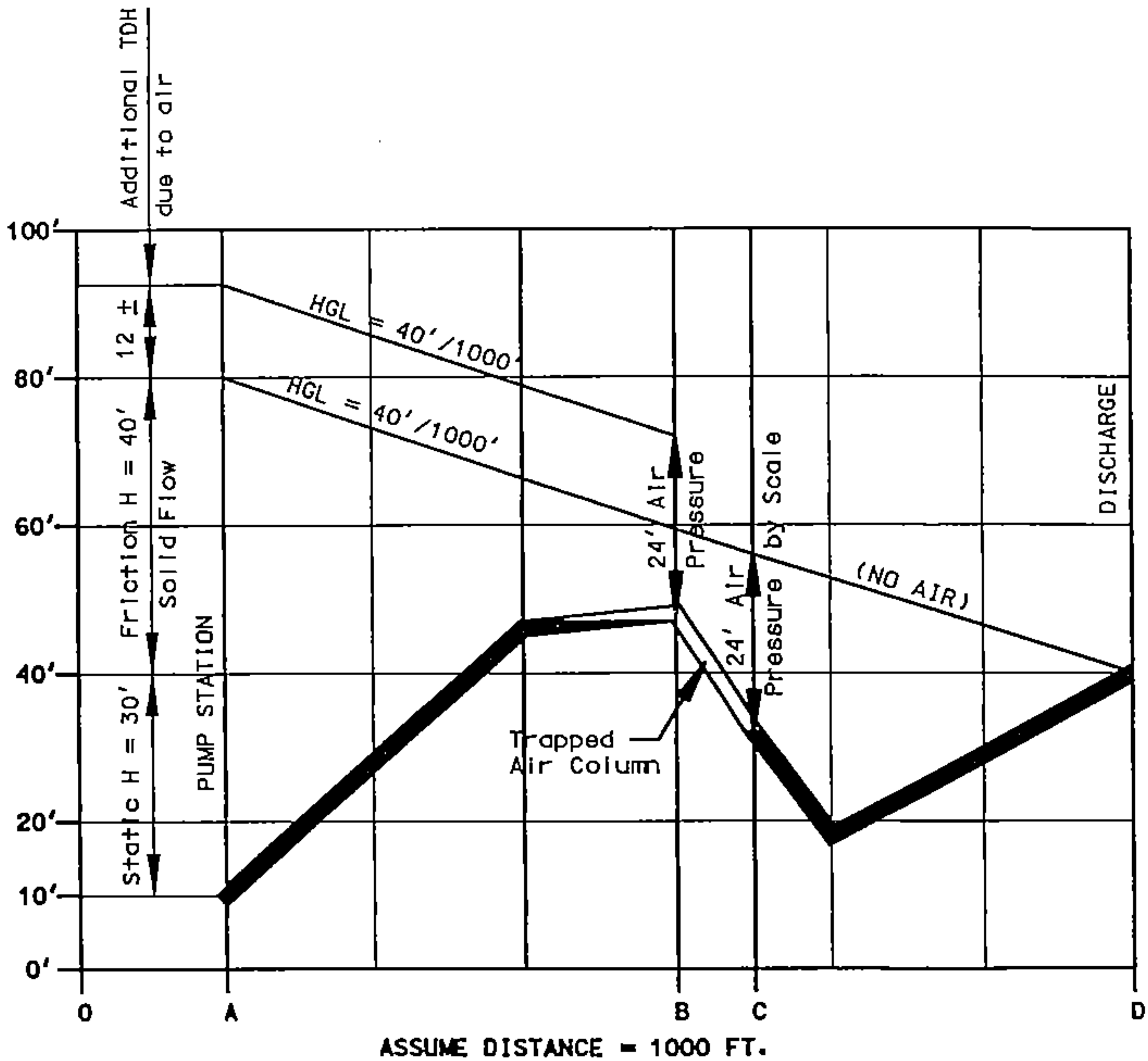


Figure 7
Effect of Air Entrapment on Pump TDH

2.18 Check Valves

2.18.1 For pump system head of 30 psi or less, the maximum velocity through a non-spring loaded or counter-weighted check valve should not exceed 3 fps. It may be increased to 5 fps for check valves which are spring loaded or counter weighted to prevent valve slamming. For pump system head higher than 30 psi cushioned swing check valves should be used. However, cushioned swing check valves do not eliminate pressure surges when the valve closes suddenly. It only reduces the slamming noise.

2.18.2 One valve manufacturer recommends that the counter-weight arm should be installed in a horizontal position when fully closed if the valve will open to an upward angle of 45 degree at the maximum operating capacity. The arm may be installed at 30 downward angle if the valve will open to an upward angle of 60 degrees or more at the maximum operating capacity. This is important in order to ensure that valve will be fully closed before the pressure wave returns to the valve location.

2.18.3 When pumps are stopped suddenly, as during a power failure, the pressure inside the force main will rise when the return pressure wave reaches the closed check valve. The amount of pressure rise may be any where between 40 to 70 percent above the normal pump operating head. Power operated check valves are sometimes used to control the pressure rise at the pump to a minimum.

2.18.4 The following standards should be used unless they are verified to the contrary by computer surge analysis.

a) The force main pipe should be specified to be capable of sustaining a negative pressure of -8 to -10 psig. The maximum surge allowance of the pipe should be about 70% of the maximum operating pressure when swing check valves are used.

b) In a high-pressure pumping system where the amount of pressure rise is severely limited, power-operated check valves should be considered. By proper selection of the valve closing time, pump back-spinning can be prevented.

c) A system where zero pressure rise is desired can be achieved by allowing sewage to return to the wet well while the check valve is closing slowly. Under such condition the maximum reverse speed of the pump must be estimated and clearly stated in the project specifications.

2.19 Shut-off Valves

Plug valves or resilient-seat, solid-wedge gate valves should be used for shut-off service in a sewage force main application when the liquid being pumped contains gritty material. Outside Yoke and Screw (OY&S) rising stem gate valves are preferred by some operators to Non-Rising Stem (NRS) gate valves because their gate positions can be readily identified. Because of the conventional type packing which is used in OY&S gate stem seals they may require occasional adjustment.

2.20 Blow-off Valves

Low points in a sewage force main should be provided with a blow-off valve especially when the sewage contains grit and other inorganic solids and the pipe slopes of the falling and rising legs are steep. The blow-off liquid may be drained to a nearby gravity sewer or be hauled away in a tank truck. If pumps can be operated once each day to provide the required flushing velocity un-interruptedly for such a duration that the volume inside the falling and rising legs can be replaced with the fresh sewage the blow-off valve may be omitted.

2.21 Air and Vacuum Valves

Sewage pump station design utilizing submersible pumps will usually have the check valves installed closer to the ground surface for easy maintenance. Such arrangement frequently requires an air and vacuum valve to be installed on the pump side of the check valve to prevent vacuum pressure being developed inside the vertical riser pipe when the pump stops; and to allow the air to be completely vented to the atmosphere with little or none being passed into the force main through the check valve. When the difference in elevation between the low wet well water level and the top of the discharge pipe, at the check valve, is less than 25 feet, air and vacuum valves may be omitted. On longer riser pipes air and vacuum valves must be installed and the following procedures may be followed in computing the valve size required:

Step 1. Determine the vertical distance in feet between the check valve and the minimum water level. If it is less than 10 feet, no vacuum relief valve is required.

Step 2. Determine the maximum pump operating capacity in cfs. Convert pump capacity in gpm to cfs by dividing by 448. This should be equal to the required valve venting capacity.

Step 3. Select the required valve size from an Air Vacuum Valve Discharge Capacity Chart similar to the one shown in Figure No. 8. Valve manufactures normally recommended 2.0 psig as the design outflow pressure, this could be reduced to 1.0 psig when frictional head loss through shut-off valve and vent pipe is included.

<u>Example</u>: Determine the size of an air and vacuum valve required to vent the air volume inside 30 feet of 16-inch riser pipe between the check valve and the minimum pumping level in the wet well, assume the maximum pump discharge capacity is 5.0 mgd (7.75 cfs).

Vertical Distance of riser pipe = 30.0 feet
Actual pump capacity,
or valve vent capacity = 7.75 cfs

Valve venting capacity from Manufacturer's Data:

1" Valve	= 2.0 cfs
2" Valve	= 5.0 cfs
3" Valve	= 10.0 cfs
4" Valve	= 13.0 cfs
6" Valve	= 32.0 cfs

Valve size Selected = 3.0 inches.

2.21.3 Since the vertical distance is greater than 10 feet, a vacuum and air release combination valve should be specified.

Sewage type air vacuum valves should be used in sewage pump station applications. These valves are furnished with flushing-out hose connections.

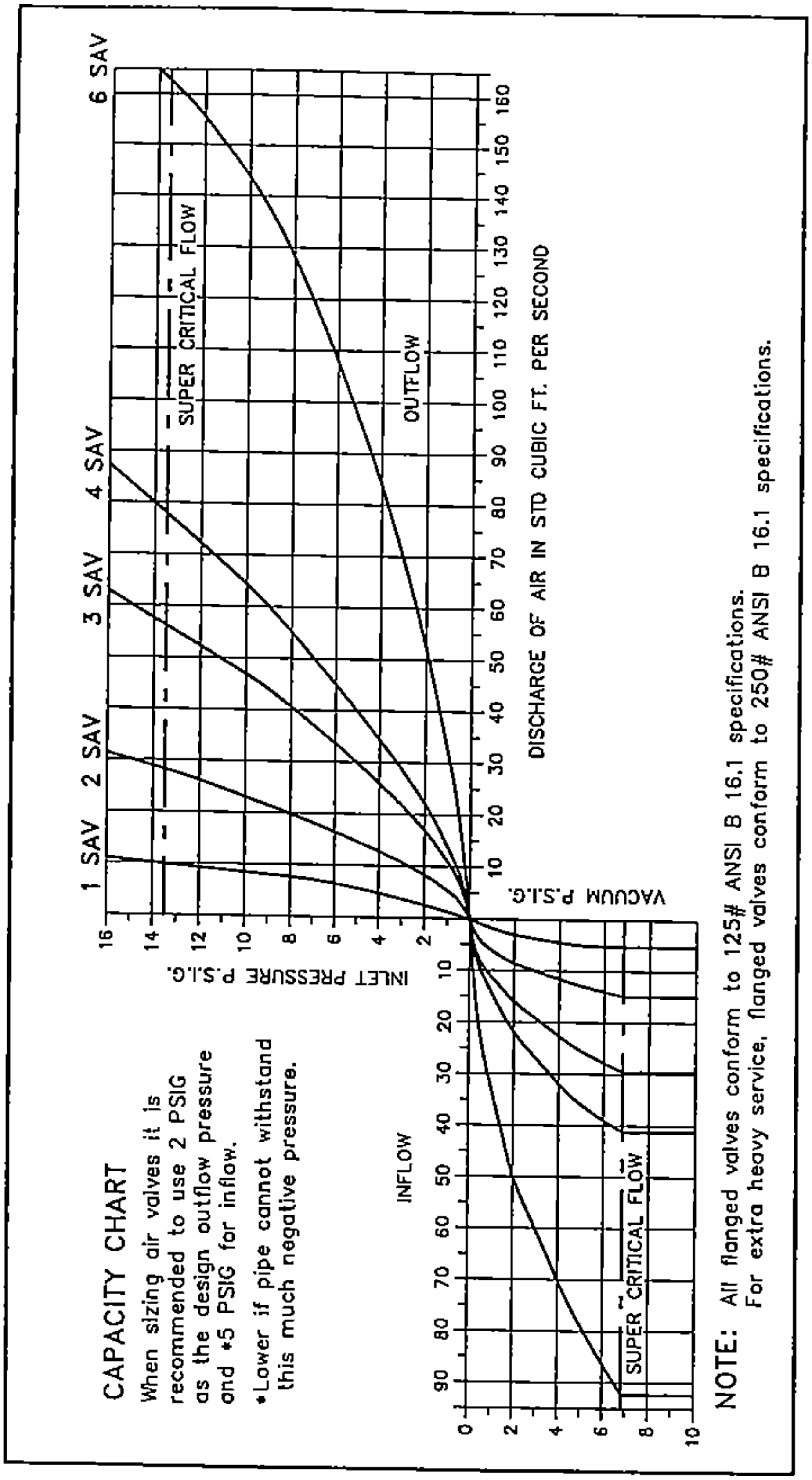


Figure 8
Air Vacuum Valve Capacity Chart

SECTION 3

STRUCTURAL DESIGN CRITERIA

SECTION 3
STRUCTURAL DESIGN CRITERIA

3.1 Specification Codes

3.1.1 The following codes, specifications, recommendations, allowable stresses, and loadings will be used in designing the project structures:

1. Uniform Building Code UBC (1991) with City of Houston Amendments.
2. Building Code Requirements for Reinforced Concrete (ACI 318-92).
3. Details and Detailing of Concrete Reinforcement (ACI 315-92).
4. Manual of Engineering and Placing Drawings for Reinforced Concrete Structures (ACI 315R-94).
5. Environmental Engineering Concrete Structures (ACI 350R-89).
6. AISC Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design (1989) and Manual of Steel Construction, Allowable Stress Design.
7. AASHTO Standard Specifications for Highway Bridges.
8. Geotechnical Report.

3.2 Loads

3.2.1 Pump Station and Valve Vault Structures Below Grade

1. Hydrostatic liquid pressure due to maximum internal operating liquid level with no balancing external lateral pressure	63 pcf
2. Poorly draining sand or sand and gravel, lateral pressure	80 pcf(min) or Per Soil Rpt.
3. Compacted silty clay, lateral pressure	100 pcf(min) or Per Soil Rpt.
4. Lateral load due to surcharge loading of construction crane and H-20 truck shall be added to load (b) and (c).	Per Soil Rpt.

5. All Structures shall be designed to resist buoyancy due to ground water at finished grade or the 100 year flood elevation, whichever is higher. See Section 3.3 for buoyancy calculation requirements.

6. Roof Slab at or below Grade:
   DL: Weight of Concrete Slab
   SDL: Backfill or other Superimposed Dead Loads
   LL: 300 psf or equipment weight plus 50 psf.

7. Fiber Reinforced plastic cover, platform, and walkways at or below grade.
   LL: 150 psf

3.2.2 Buildings and Miscellaneous Structures

Loadings for design of buildings to be obtained from appropriate codes. However, certain minimum loads shall be used as follows:

<u>Minimum Uniform Live Loads</u>:

Grating	150 psf
Stairs and catwalks	150 psf
Electrical control rooms	250 psf

(Estimate support area and equipment weights and assume loads applied anywhere in area in question)

Wind: As per UBC for basic wind speed = 90 mph. Exposure C and Importance factor = 1.15

3.3 Buoyancy

The below grade wet wells and valve vaults will be subject to buoyant forces as defined in Section 3.2. The calculation shall use the safety factors and follow the method presented in Figure 9. Since a bentonite slurry may be used in the caisson excavation, the safety factor listed for soil friction reflects its presence. Verify that the required factors given by the geotechnical consultant are consistent with this. The structure weight shall only include the walls and slabs. The weight of fillets, baffle walls, pads, and equipment shall not be included as these could be changed in the future or may not be in place during construction.

3.4 Design Stresses

3.4.1 Concrete and Reinforcing Steel

1. Liquid Containing Structures:
   Use Strength Design Method of ACI 318-89,
   Building Code Requirements for Reinforced Concrete, with durability factor per ACI 350 R-89 Environmental Engineering Concrete Structures, and base crack control on a maximum Z of 115.

Concrete compressive strength at 28 days	fc = 4,000 psi
Reinforcing steel (A 615, Gr. 60)	fy = 60,000 psi

2. Building and Non-Liquid Containing Structures:
   Use Strength Design Method of ACI 318-89

Concrete compressive strength at 28 days	fc = 4,000 psi
Reinforcing steel (A 615, Gr. 60)	fy = 60,000 psi

3.4.2 Structural Steel

Follow AISC Specification for the Design, Fabrication and Erection of Structural Steel for Building (1989), and use following materials:

1. ASTM A36 unless otherwise specified
2. ASTM A325 H.S. bolts
3. ASTM A307 or A36 bar stock for anchor bolts

3.5 Design Considerations

3.5.1 Wet Well Load Cases:

1. Wet well empty with full lateral exterior load.
2. Wet well filled to the maximum level possible during a power outage, while disregarding exterior soil pressures.

3.5.2 Differential Soil Movement:

Due to the significant difference in foundation elevations between the wet well and the valve slab or vault, there is a potential for differential soil movement resulting from settlement, expansive clays, or movement needed to develop soil friction. This potential movement is most severe where wet wells are constructed by the caisson method. The open cut construction method allows for placing cement stabilized sand so as to minimize the movement potential. The Guideline Drawings include expansion or rotation joints.

3.5.3 Wet Well Wall Design

1. The circular wet well shall be designed using a recognized shell theory or by using the Portland Cement Association publication, "Circular Concrete Tanks without Prestressing."

2. The Guideline Drawing indicates dowels connecting the wall to the base slab for the caisson construction method. Structural connections between base slab and caisson shall be designed to transfer full base reactions from slab to wall. Full base reactions are:

    a. For downward load: weight of components supported on the slab plus the weight of liquid at maximum elevation in the wet well;

    b. For upward load: (1) soil bearing reactions; and (2) hydrostatic uplift pressures, together with any potential soil uplift pressure caused by instability, for empty well. Hydrostatic pressure shall be as defined in Paragraph 3.2.1 Soil uplift pressures shall be based on geotechnical analysis.

3. Wall Base Cutting Shoe Details

   a. The minimum depth of the cutting shoe base below the final excavation bottom shall be shown on the drawings. The required depth to maintain bottom stability shall be based on geotechnical analyses. In no case shall the required minimum depth of shoe penetration below the final excavation bottom be less than 1.5 feet.

   b. Under no circumstances shall the excavation depth shown on the drawings require excavation below the top of the inside bevel of the cutting shoe.

3.5.4 Additional Stresses Due to Caisson Construction

If the contractor (at his option) selects to utilize caisson construction method, the following additional stresses shall be added to stresses from sections 3.5.1, 3.5.2 and 3.5.3.

1. Tilting or out of plumbness may occur during sinking of caisson. Tilting shall be not more than 1-inch per 5 foot depth of caisson. Tilting causes bending stresses in the caisson wall. These additional stresses shall be included in the design of caisson wall.

2. Sudden sinking causes axial tension in caisson wall. When frictional and adhesional forces on upper length of caisson are equal to total weight of caisson, caisson sinking stops. This stoppage causes hang-up forces resulting in axial tension in caisson wall. Minimum hang-up force equal to one half the weight of caisson shall be used in design of longitudinal reinforcement in caisson wall.

3.5.5 Control Building Design

Unless the control building dimensions are changed from what is shown on the guide drawings, only the foundation needs to be designed. Follow the recommendations of the geotechnical report for the type and depth of the foundation.

3.5.6 Valve Vault Catwalks

Access over pipes which extend to greater than 30 inches above the floor shall be by catwalk as detailed on the guideline drawings. The fiberglass specifications call for the catwalk to be designed by the manufacturer. The drawings need to provide all the dimensions and approximate support leg locations.

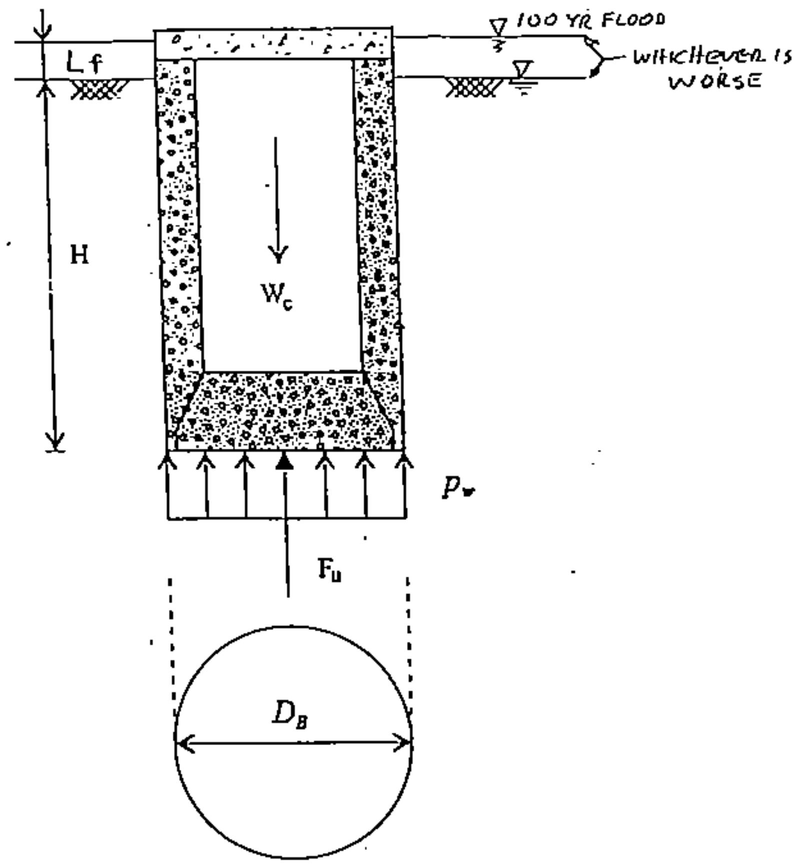
3.6 Detailing

3.6.1 Detailing of the reinforcement shall follow the requirements of ACI 315, ACI 315R, ACI 318, and ACI 350R.

3.6.2 All construction joints in water containing and below grade elements shall be provided with a 6 inch PVC waterstop. All expansion joints shall be provided with a 9 inch PVC centerbulb waterstop. Where construction requirement or joint geometry will not allow a

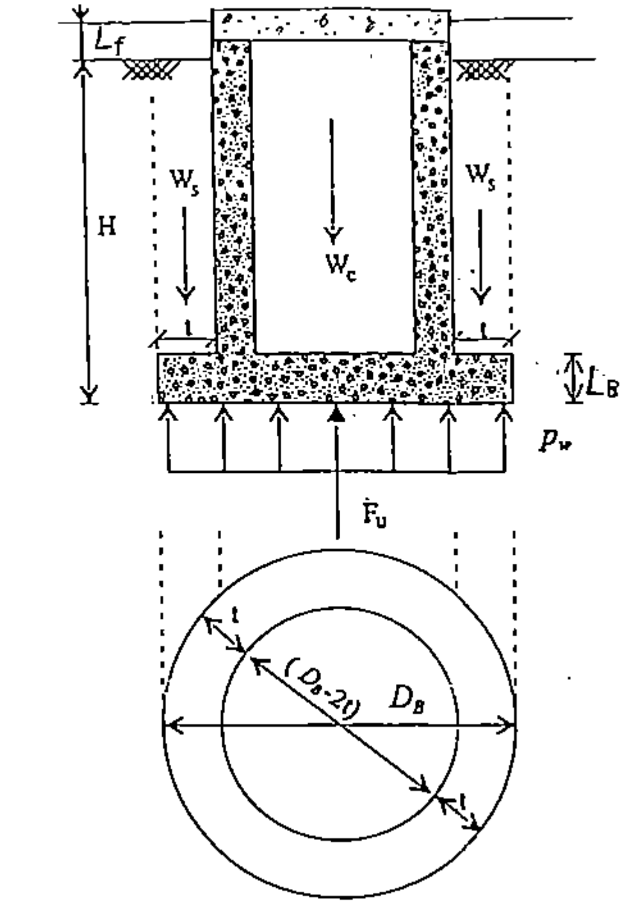
6 inch PVC waterstop, a surface applied waterstop which forms a positive seal by adhesion or expanding in the presence of water may be used. Notes and/or details shall be added to insure that all joints and joint intersections are continuously sealed.

(a) UTILIZING STRUCTURAL WEIGHT



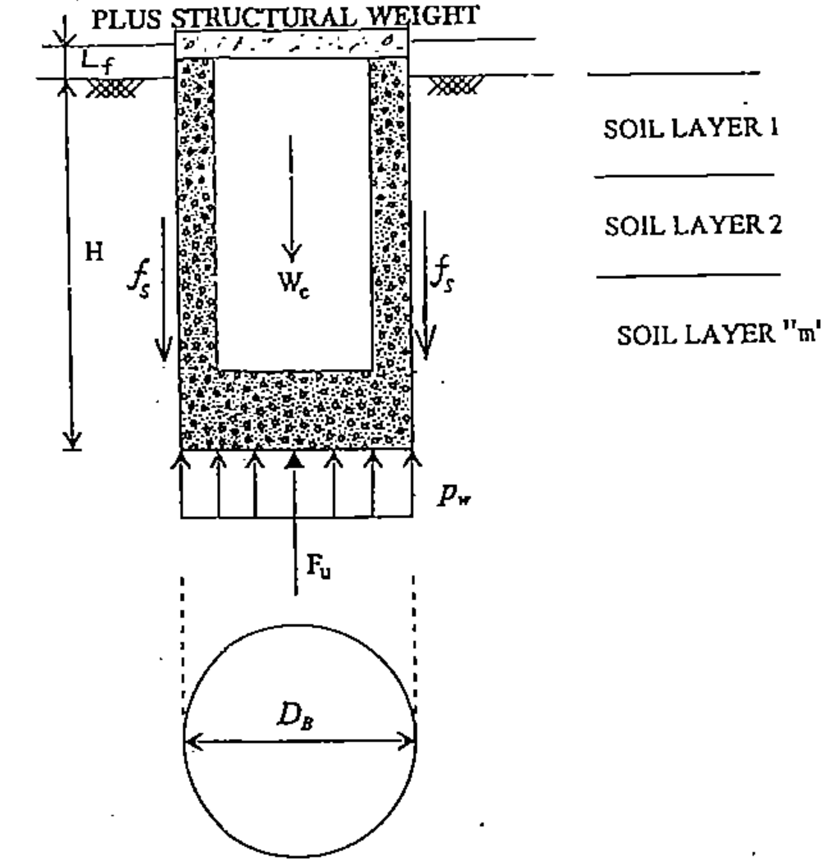
$$p_w = (H + L_f)\,\gamma_w$$
$$F_u = A_B\,p_w$$
$$W_c = V_c\,\gamma_c$$
$$\frac{W_c}{S_{f_a}} \geq F_u$$

(b) UTILIZING SOIL WEIGHT ABOVE BASE EXTENSION PLUS STRUCTURAL WEIGHT



$$W_s = [\quad (H \quad - L_B)\,(\gamma_s' + \gamma_w)\,]\,[\,\pi\,t\,(D_B - t)\,]$$
$$\frac{W_c}{S_{f_a}} + \frac{W_s}{S_{f_b}} \geq F_u$$

(c) UTILIZING WALL/SOIL FRICTION PLUS STRUCTURAL WEIGHT



$$f_{s_m} \text{ (cohesive soils) } = \alpha\, c_m$$
$$f_{s_m} \text{ (cohesionless soils) } = \frac{(\sigma_{v_{m-1}} + \sigma_{v_m})}{2}\, K \tan\delta_m$$
$$\frac{W_c}{S_{f_a}} + \frac{\pi D_B \sum f_{s_m} L_m}{S_{f_c}} \geq F_u$$

where:

$h_o = 0$

$\sigma_{v_o} = 0$

For $h_m > H$, use $L_m = H - h_{m-1}$

$$\sigma_{v_m} = \sigma_{v_{m-1}} + \gamma'_m\, L_m$$

Where:
- A_B = area of base, sq ft
- c_m = undrained cohesion of soil layer "m", psf *
- D_B = diameter of base, ft
- F_u = hydrostatic uplift force, lbs
- f_{sm} = average frictional resistance of layer "m", psf
- H = height of buried structure, ft
- h_m = depth to bottom of soil layer "m", ft
- K = coefficient of lateral pressure *
- L_B = thickness of base extension, ft
- L_f = distance to finished grade to 100 yr flood elev, ft
- L_m = thickness of soil layer "m", ft
- p_w = unit hydrostatic uplift, psf
- S_{fa} = 1.10, factor of safety against uplift, concrete weight
- S_{fb} = 1.50, factor of safety against uplift, soil weight
- S_{fc} = 3.00, factor of safety against uplift, soil friction
- t = width of base extension, ft
- V_c = volume of concrete (walls and slabs only), cu ft
- W_c = weight of concrete structure, lbs
- W_s = weight of backfill above base extension, lbs
- α = cohesion reduction factor *
- γ_s = unit weight of damp backfill, pcf (use 125 pcf for compacted backfill) *
- γ_s' = submerged (effective) unit weight of backfill, pcf (use 62.5 pcf for compacted backfill) *
- γ_m = submerged (effective) unit weight of soil layer "m", pcf *
- γ_c = unit weight of concrete = 145 pcf
- γ_w = unit weight of water = 62.4 pcf
- σ_{vm} = overburden pressure at bottom of layer "m", psf
- δ_m = friction angle between soil layer "m" and concrete wall, degrees *
- ϕ_m = internal angle of friction of soil layer "m", degrees *

* obtain value from the site specific geotechnical report

Notes:

- cohesive soils include clay, sandy/silty clay.
- cohesionless soils include silty sand, sandy/clayey silt.
- neglect f_s in upper 5 feet.

UPLIFT PRESSURE AND RESISTANCE

Figure 9

SECTION 4

MECHANICAL DESIGN CRITERIA

SECTION 4
MECHANICAL DESIGN CRITERIA

4.1 General

4.1. This design guide gives criteria and describes procedures for designing of cooling, ventilation and plumbing systems for lift stations. The lift stations include a wet well, and may include either a control building or an outdoor control panel. The valves and discharge piping may be above grade or in a vault below ground depending on specific site requirements.

4.1.2 The wet well is a strictly unattended well with submersible pumps. The submersible pumps can be removed from the wet well through the use of a rail guide removal system without the necessity of entering the pit. The Wet Well must not be entered under any circumstances without first providing proper ventilation to remove any explosive or toxic fumes that may be present in it.

4.1.3 The valve vault houses isolation and check valves, and could house other devices which may require periodic checking. The vault can be entered through a hatch and a vertical ladder. Before entering the vault, it must be properly ventilated.

4.1.4 The control building houses motor control centers, panels, transformers and other equipment required for the lift station operation.

4.1.5 Because of solar heat transmission into the control building and heat gains from electrical equipment, the building must be provided with proper cooling to prevent overheating and possible malfunction of electrical devices.

4.1.6 The design should be in compliance with applicable criteria by TNRCC codes and NFPA 820, Standard for Fire Protection in Watewater Treatment and Collection Facilities.

4.2 Wet Well Ventilation

4.2.1 Since the wet well is unattended and must not be entered without special provisions, a permanent type ventilation system is not required. Mechanical ventilation must be provided when the wet well is to be entered for any reason. A portable type engine or electrically driven air supply fan should be used. A quantity of outdoor air, equal to at lease thirty air changes per hour of the wet well volume must be blown into the well through a flexible pipe. The point of discharge of the air into the well must be where people are present. The air supply fan must be in operation for a minimum of two minutes before anyone enters the well. Entrance hatches must be kept open to allow foul air to escape from the well while outdoor air is being blown in.

4.2.2 The ventilation for a wet well should be designed as a passive gravity ventilation system (breather type), where the air volume in the well is either increased or outdoors through the vent pipe, as sewage flows into or is pumped out of the wet well. The passive ventilation pipe should be sized to allow an inflow of make-up air volume to the wet well, at a rate equal to the maximum liquid pumping rate out of the wet well, with an air velocity through the vent pipe not to exceed 600 fpm. In no case shall the vent pipe be less than six inches in size.

4.3 Valve Vault Ventilation

4.3.1 The valve vault is normally unattended. However, on occasion it must be entered to service valves and other devices. A ladder is provided for that purpose.

4.3.2 Since odors are not normally generated in the vault, continuous ventilation and odor control are not required. There is a possibility, however, that harmful or explosive fumes may enter the vault through cracks in walls or leaking valves. For this reason, the vault must be properly ventilated before anyone enters it. The ventilation should be accomplished with a permanently installed in line air fan. Outdoor air should enter the vault through open vault access hatches. The fan should run for at least two minutes, supplying outdoor air to the vault before anyone enters it.

4.3.3 The fan should be installed vertically and supported from the vault wall. The outdoor pipe should be either FRP (fiberglass reinforced plastic) or PVC (poly vinyl chloride) pipe, and should conform to either of the two details (No. 9 or 9A) supplied in the Design Guidelines Drawing package. Selection of gooseneck on mushroom type venting shall be based on direction from City of Houston Wastewater Operations.

4.3.4 The fan should be sized for 30 air changes per hour of the vault volume. If the vault volume is 1200 cubic feet then the fan capacity should be 1200 cf per air change x 30 air changes per hour x one hour/60 minutes = 600 cfm.

4.3.5 Construction of the fan should be FRP material, with a spark proof aluminum or FRP wheel and an explosion proof, direct or belt drive motor.

4.3.6 Air piping should be sized for a maximum pressure drop in inches of water column per hundred equivalent feet of pipe or duct as follows: 0 to 600 cfm -0.08 inches wc; 600 to 2000 cfm - 0.10 inches wc; 2000 to 4500 cfm - 0.125 inches wc. The minimum size of the pipe should be 6 inches in diameter.

4.3.7 An enamel sign should be installed at the vault entrance hatch in an easily visible place and indicate the following warning:

> "START FAN, KEEP ENTRANCE HATCHES OPEN, BE SURE FAN IS RUNNING, WAIT 2 MINUTES BEFORE ENTERING."

4.4 Plumbing

4.4.1 Water from open grating pump access hatches, cracks in walls and floor may leak into the valve vault. Liquids from leaky valves or from valves under repair may also be discharged onto the vault floor. A floor drain to drain the liquids to the adjacent wet well should be provided. The floor drain should have a "P" trap and a floating ball-type backwater valve to prevent fumes and liquids from entering the vault from the wet well. The valve vault floor should be sloped toward the floor drain.

4.4.2 Where solid pump access hatches are used, a corrosion resistant sump pump system should be provided to pump the liquid to the adjacent wet well.

4.4.3 A water supply is needed during repairs, for washing down equipment, valve vault and grade slabs. Water should be provided through a 3/4 inch diameter supply line and non-freeze type hose bibb located near the wet well.

4.4.4 All water should be metered and supplied through a reduced pressure type backflow preventer for protection of the city water mains from possible contamination due to cross-connections.

4.4.5 The above grade water supply system pipe, fitting, valves, and water meter should be insulated and protected against freezing. The complete backflow preventer assembly should be provided with a vandal proof enclosure and equipped with access provisions for servicing and checking of the equipment.

4.5 Control Building Cooling

4.5.1 Control Buildings house motor control centers, electrical panels transformers, and other equipment for operating pumps located in Wet Wells.

4.5.2 The temperature in the buildings will be affected by solar heat gain, by thermal conduction and convection, and by heat radiated from electrical equipment. If the excess heat is not removed either with ventilation air or by mechanical cooling, the temperature in the building will rise to a point where electrical devices will malfunction and disrupt operation of the pumping station.

4.5.3 Where clean outdoor air at suitable temperatures is available, forced ventilation is the least expensive and simplest way of removing heat from a building. Removing heat by forced ventilation should be considered when it is possible to maintain indoor temperatures of not to exceed 105 degrees fahrenheit at all times. In Houston, however, outdoor air may at times be very saline, and when drawn through a building will cause corrosion and adversely affect delicate electrical instruments and devices. Therefore, controlling building temperature in such atmospheres is best accomplished by providing mechanical cooling units, where minimum or no outdoor air is circulated through the building, thus avoiding possible corrosion of equipment.

4.5.4 The mechanical cooling units are also susceptible to corrosion from the saline atmosphere. The useful life of such units will be much shorter in a saline atmosphere than in normal atmospheric conditions. However, the operating life of mechanical units can be extended by specifying that the units will be provided with a protective coating application. Heat transfer capacity of protectively coated coils is not significantly affected (normally a reduction in capacity of less than 10 percent). The coating should cover all parts that come in contact with outdoor air, which includes the casing, heat transfer coils, refrigerant tubing and electrical devices. Mechanical cooling units should be wall mounted package type, heat type, units.

4.5.5 When sizing the cooling unit, all instantaneous sources of heat gain must be accounted for. The worst scenario would be with all pumps running and the outdoor temperature 100°F, or higher, and staying within this range for a number of consecutive days. Mechanical cooling units shall be sized to maintain a building indoor temperature of 85 degrees fahrenheit or less at a 40 percent specific humidity at maximum heat gain.

4.5.6 Solar and transmitted heat gain calculations must be in accordance with the ASHRAE Handbook of Fundamentals. The outdoor temperature listed in the ASHRAE Guide must be adjusted for outdoor air temperature encountered in Houston, if such maximum temperature continues within that range for more than 4 hours. Maximum temperatures for the particular area must be obtained locally.

4.5.7 Unit Selection should be based on a terminal wall mounted heat pump type mechanical cooling unit having a minimum 13,000 BTUH sensible cooling capacity at 105°F outdoor air temperature at 77°F wet bulb temperature and an air temperature of 85°F dry bulb and 66°F wet bulb entering the cooling coil.

4.5.8 The above selected unit is sized for a 4-pump system. The same unit can also be used for stations with fewer pumps and smaller heat gains.

4.5.9 The air conditioning unit should be controlled through a room type thermostat set to maintain the room air temperature at approximately 80°F. The unit fan shall run continuously when the unit control switch is in the "on" position.

SECTION 5

ELECTRIC POWER AND INSTRUMENTATION CONTROLS DESIGN CRITERIA

SECTION 5

ELECTRICAL POWER AND INSTRUMENTATION CONTROLS DESIGN CRITERIA

5.1 Basic Data

5.1.1 Prior to assembling a drawing package, the following site specific data must be established and calculations performed. Refer to the current Design Guideline Manual for guidance on fencing requirements, site layout, location of electrical junction boxes, etc.

- Number and size of pumps (gpm & HP/KW)
- Station configuration (Preferred, Secured Site or Exposed Site)
- Location of electrical junction box (above grade or in valve vault)
- Instrumentation system level (Level I, II or III)
- Fencing requirements
- Electrical power reliability study for alternate power determination
- Full load calculation
- Motor starting analysis and short circuit calculations

5.2 Electrical Drawing Set

5.2.1 Each design package shall contain the following minimum electrical drawings:

- Electrical Symbols Legend, Lighting Fixture Schedule & Abbreviations
- Site plan, including grounding and outdoor lighting
- Conduit Layout Plan
- Conduit Layout Sections
- Electrical Design Details
- Control Building Plan (for sites with control buildings)
- Control Cabinet Layout
- Process and Instrumentation Diagram
- Control System Wiring Diagrams
- MCC & PLC Power Schematic Wiring
- Single Line Diagram
- Cable and Conduit Schedule
- Device Rating Schedule
- MCC Elevation (for sites with a MCC)

5.2.2 The electrical drawing set is arranged with Guideline plans and details for Level I lift stations with two pumps, and for Level II or Level III lift stations with up to 6 pumps (4 wet weather and 2 dry weather pumps). The contracted design engineer is responsible for adjusting the details in the drawings, the number of pump starters, relays, devices, et cetera, based on the specific configuration. Delete only the devices associated with pumps not provided. DO NOT delete items associated with provided pumps without prior approval of the City of Houston. Some components have been included to provide for ease of future expansion.

5.3 Electrical Symbols, Legend, Lighting Fixture Schedule & Abbreviations Sheet

5.3.1 This sheet defines the symbols and abbreviations utilized in the preparation of the contract drawing package, and schedules the lighting fixtures used. Use this sheet as a guideline for revisions made to the Guideline Drawings

5.3.2 ***Include this sheet in each design package. DO NOT delete symbols or abbreviations from this sheet. Add any special items used in the preparation of the final package. Delete any lighting fixtures not used.***

5.4 Site Plan

5.4.1 In addition to the Design Guideline Drawings required, a site specific electrical site plan must be created. After establishment of the basic civil site, the following electrical information must be established and/or added:

- Locate the electrical building or electrical panel in accordance with the COH Design Guidelines.
- Locate the electrical service point.
- Orientate the lift station to coincide with the civil plans.
- Route conduits from electrical service and telephone service locations to the control building/cabinet.
- Locate yard light and route conduit from control building/cabinet.
- Establish site ground field and provide ground connections of service entrance, control building/cabinet, handrails, above grade electrical junction boxes, yard light, piping and all metal parts.

5.4.2 Note: An example of an electrical site plans is included in the Design Guideline Drawing package as referenced material for the Design Engineering.

DO NOT include this drawing in the project drawing package without site specific modifications.

5.5 Electrical Plans and Sections

5.5.1 From the Standard Design Guideline Drawings, select the following drawings for the appropriate lift station configuration and size. Review all drawings and details and revise to accommodate specific site and facility requirements. At a minimum, the following review and revisions are required:

- Verify structural dimensions of the valve vault and the wet well and revise the electrical plans accordingly
- Verify the number of active air cell conduits based on the applicable instrument system. **Provide adequate air cell and electrical installed spare conduit for anticipated future use.**
- Verify drawing number cross references for section callouts
- Verify all sections referenced are included in the document set

- Orient station plans and conduit layout sheets to correspond with the site plan
- Adjust north arrow on each plan sheet
- Add any special or extra features required at this specific site. **DO NOT use conduits designated as "future space" for undesignated additions.**
- Determine the need for power factor correction capacitors and locate on the drawings. Connect capacitors to the motor starter leads prior to the motor overload relay. Exercise caution to specify capacitors with overcurrent fuses and indicating lights then locate capacitors within the 25 wire feet distance specified by the N.E.C. Article 240-21.

5.6 Typical Details

5.6.1 The typical electrical details are to be revised and combined as necessary to meet specific site conditions. In general, the details apply to the following situations:

Detail 3 (Z0E02) - Beginning Junction Box	To be used at all lift stations with Level II or III Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 3A (Z0E02) - Beginning Junction Box	To be used at all lift stations with Level I Single Phase Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 3B (Z0E02) - Beginning Junction Box	To be used at all lift stations with Level I Three Phase Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 4 (Z0E02) - Intermediate Junction Box	To be used at all three and five pump lift stations with Level II or III Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 5 (Z0E02) - End Junction Box	To be used at all lift stations with Level II or III Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.

Detail 5A (Z0E02) - End Junction Box	To be used at all lift stations with Level I Single Phase Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 5B (Z0E02) - End Junction Box	To be used at all lift stations with Level I Three Phase Instrumentation. Control conductors for pumps less than 50 HP may be in a common cable with power conductors. Adjust the number of conductors and conduits accordingly.
Detail 6 (Z0E03) -	Air cell conduit details to assist in installation.
Detail 7 (Z0E03) - Typical Ductbank Section	To be used at all lift stations.
Detail 8 (Z0E03) - Typical Ductbank Entrance at Structural Wall	To be used in conjunction with Detail 10 at all lift stations with valve vaults.
Detail 9 (Z0E03) - Typical Electrical Handhole Construction	Special detail for use where an electrical handhole is necessary. Possible applications are as an intermediate pull location for long underground ductbanks.
Detail 10 (Z0E03) - Typical Conduit Seals	To be used at all lift stations with a electrical building, and in conjunction with Detail 8 at all lift stations with a valve vault.
Detail 11 - Deleted	
Detail 12 (Z0E04) - Typical Yard Light	To be used at all lift stations. Delete the flashing alarm light at sites with a control building. Verify foundation design for specific site soil conditions.
Detail 13 (Z0E04) - Electric & Telephone Service Installation Detail	To be used at all lift stations with aerial service. Provide telephone service for Level II & III Instrumentation. Provide spare telephone conduit for Level I stations. Verify and coordinate all specifics with HL&P and SWB.
Detail 14 (Z0E04) - Typical Ground Well Installation	To be used at all lift stations.

Detail 15 (Z0E04) - Typical MCC & Control Panel Instrumentation & Conduit Entry	To be used at all lift stations with interior MCC's or Control Panels.
Detail 16 (Z0E04) - Typical Panel Installation	To be used at all lift stations with a distribution panel in the control building.

5.7 Control Building Plan

Include this sheet in each lift station package with a control building. Revise building dimensions, number of MCC sections, telephone service and conduit plan based on the number and size of pumps and instrumentation system level. (Control Building dimensions are provided on the Device Rating Schedules). Orient the building plans and add a north arrow to coordinate with the site plan. Revise lightning protection details to coordinate with actual building construction and materials. Relocate alarm light to provide visibility from access road.

5.8 Control Cabinet Layout

Based on the instrumentation system level and the intended location of the control cabinet (indoor or outdoor), select the appropriate control cabinet installation and equipment layout sheet(s). Revise the dimensions, elevation, device layout and air piping schematics based on the actual number of pumps. The Level II outdoor power and control cabinets are shown back-to-back in a single four door enclosure. For installations where this approach is not feasible, the designer must separate the two sections (shown as the front control panel and the back power panel), adjust enclosure depth, and provide interconnecting wiring required for the number of pumps used.

5.9 Process and Instrumentation Diagrams

Based on the instrumentation system level, select the appropriate process and instrumentation diagrams. Revise by deleting unnecessary devices based on number of pumps. Do not renumber or adjust input/output designations. Label all unused PLC input/outputs as spare.

5.10 Control System Wiring Diagrams

Based on the instrumentation system level, select the appropriate control system schematic diagrams. Revise by deleting unnecessary devices based on number of pumps. Do not renumber or adjust line numbers or input/output designations. Label all unused PLC input/output as spare.

5.11 MCC & Power Wiring Diagram

Select the appropriate diagram and revise to reflect actual number of pumps, valve vault exhaust fan, service voltage and other site specific conditions.

5.12 Single Line Diagrams

Based on the location of the motor controls and the instrumentation level, select the appropriate diagram. Revise the selected single line diagram to reflect actual number of pumps, service voltage, use of a valve vault, use of a lighting transformer, etc. Coordinate service entrance and metering requirements with HL&P.

5.13 Conduit Schedule

Prepare a site specific conduit schedule by revising the following columns from the appropriate guideline sheet:

- Conduit Number
- Description
- Service (Voltage and Amps / HP)
- Routing (From, To, Via)
- Conduit Description and Size
- Cable ~~of~~ or Wire Description and Conductor Size

Revise the table to provide conduit and wire sizes and descriptions in accordance with NEC requirements for actual site conditions. Conduits not necessary at a specific site, should be deleted from the schedule. Show conduits to be installed for future use as "Installed Spare" or " Future Space" on the Schedule.

Notes to the Design Engineer are provided to assist the designer in selecting conduits for certain special installations. Revise the conduit schedule selected based on the appropriate notes. Delete the notes from the final document.

5.14 Device Ratings Schedule

Prepare a site specific device ratings schedule by including the following columns from the appropriate sheets:

- Item
- Circuit
- Description
- Rating (Select the column that corresponds to the number and size of pumps at the site.)

All pump sizes are specified in standard motor horsepowers. For submersible pumps that do not precisely coordinate with these standard horsepowers, select the table for the next larger size.

Verify that device ratings selected are in accordance with current NEC requirements.

5.15 MCC Elevation

For sites that include a MCC, include the MCC elevation specified on the device rating schedule for the appropriate number of pumps, and horsepower ratings required.

SECTION 6

NON-CITY OF HOUSTON OWNED LIFT STATIONS

SECTION 6
NON-CITY OF HOUSTON OWNED LIFT STATIONS

6.1 GENERAL

6.1.1 This section is applicable to design of lift stations within the City of Houston jurisdiction but not owned by the City

6.2 DESIGN REQUIREMENTS

6.2.1 Ownership

6.2.1.1 Site shall be conveyed in fee to a utility district, the City of Houston, or other acceptable public entity.

6.2.1.2 The site may be part of a larger site that includes a public wastewater treatment facility or other facility.

6.2.2 Site Layout Geometry

6.2.2.1 Site shall have a minimum size of 50 feet by 50 feet.

6.2.2.2 Site access shall be provided by a 15-foot wide public right-of-way.

6.2.2.3 Wet well or dry well structures shall be a minimum of 12 feet from outside walls of structure to site boundary fencing.

6.2.2.4 Provide an all-weather road of not less than 12 feet in width to the site.

6.2.3 Fencing

6.2.3.1 Enclose all sites with an intruder-resistant fence with a (1) minimum height of 6 feet and topped with three strands of barbed wire, or (2) a fence with a minimum height of 8 feet without barbed wire.Fences, including barbed wire if used, shall be located completely inside the site boundary.

6.2.3.2 Fencing may be of any of the following construction:

1. Chain link.
2. Chain link with wood slats or plastic slats.
3. Cedar picket, 6-inch wide minimum picket with pickets bolted or screwed to steel frames connected to galvanized steel posts.

4. Precast concrete or other masonry.

5. Any other as approved by City Engineer.

6.2.4 Grading and Drainage

6.2.4.1 Use drainage swales, sidewalls and driveways, culverts, storm sewers, or a combination thereof for internal site drainage.

6.2.4.2 Site drainage may sheet flow to a public right-of-way.

6.2.4.3 Storm sewer systems, if provided shall be sized in accordance with applicable design guidelines.

6.3 WET WELL / VALVE VAULT DESIGN

6.3.1 Location

6.3.1.1 Flood Protection. The top of the wet well shall be located above the 100-year floodplain, and the design engineer shall take into consideration wave action, which may exceed this elevation. Entry to the site must be accessible during a 25-year flood.

6.3.1.2 Wet Wells. All gravity sanitary sewers discharging to the wet well shall be located where the invert elevation is at or above the liquid level of the highest pump's "ON" setting to achieve the firm pumping capacity. Gate valves and check valves shall not be located in the wet well, but may be located in a valve vault or on a concrete slab. Piping shall be spaced to maintain the pump manufacturer's minimum clearances between pumps.

6.3.2 Specifications

6.3.2.1 Size the diameter of the wet well, hatches, and hatch spacing to accommodate the selected pumping equipment. Consideration should be given to the dimensions of the ultimate pump in a multi-phased lift station to ensure adequate clearances. Provide a minimum of 6 inches of clearance from the inside wet well wall to all flanges to enable removal of all bolts. The following wet well diameters shall be used for cast-in-place wet wells: 6’, 8’, 11’, 14’, 16’-6”. Wet wells larger than 16’-6” may be sized in 1-foot increments. Precast concrete wet wells may be used in any diameter provided calculations demonstrate that wet well thickness and material weight will resist imposed up-lift pressure. Refer to paragraph 6.3.2.10. Provide hatch safety nets with aluminum sliding rails.

6.3.2.2 The wet well volume shall be based on the minimum cycle time of the largest pump planned for the lift station plus additional depth to prevent motor overheating and vortexing. The cycle time shall not be less than those listed below:

Pump Horsepower	Minimum Cycle Times (minutes)
Less than 50	6
50-100	10
Over 100	15

The minimum effective volume of the wet well shall be based on the following formula:

$$V = \frac{Q_p\, t}{(4)\, 7.48}$$

V = Volume (ft^3)
Qp = Pump Capacity (GPM)
t = Cycle Time (Minutes)
7.48 = conversion factor in gallons/cubic foot

The pump capacity "Qp" is the largest pump in alternation. This capacity is to be the actual flow rate of one pump pumping alone against a system head generated with new pipe friction factors (C=140 for PVC and for DIP).

6.3.2.3 The "OFF" elevation of the wet weather pumps shall be deep enough to prevent vortexing and motor overheating. The design engineer shall verify with <u>all</u> pump manufacturers on the List of Acceptable Manufacturers that each pump is capable of operating continuously at the "OFF" elevation shown on the plans.

6.3.2.4 Wet Well Slopes. The wet well floors shall have a minimum of 10 percent slope to the pump intakes and have a smooth finish. There shall be no wet well projections, which will allow deposition of solids under normal operating conditions.

6.3.2.5 Venting. The wet well shall have a vent sized such that the maximum velocity of air through the vent is 600 fpm at the firm pumping capacity. Vents shall have a stainless steel insect screen that is easily replaceable and will prevent the entrance of rainwater. Vent pipes shall be corrosion-resistant.

6.3.2.6 Dry Well/Valve Vault Access. Access shall be provided to underground dry wells and valve vaults. Stairways shall have corrosion-resistant, non-slip steps and conform to OSHA regulations with respect to rise and run. Where ladders are utilized in lieu of stairways, ladders shall conform to OSHA requirements.

6.3.2.7 Dry Well/Valve Vault Drains. Floor drains from dry wells and valve vaults to wet wells shall be designed to prevent gas and raw sewer water from entering the valve vault. Such designs shall include "P" traps and floating ball type backwater valves.

6.3.2.8 Dry Well/Valve Vault Clearances. All walls shall be a minimum of 18 inches from the outermost edge of all flanges to enable removal of all bolts. Pipes shall have a minimum spacing greater than that required by the pump manufacturer for minimum pump spacing. Swing check valves shall be positioned such that the shafts may be removed without removing the valve body.

6.3.2.9 Structural Considerations. Follow the latest version of ACI 350 with the exception that the minimum concrete cover over steel reinforcing shall be 4 inches where in contact with raw sanitary sewer.

6.3.2.10 Wet wells are to be designed to resist the effects of buoyancy assuming full saturation of the surrounding soils to the finished grade or the 100-year floodplain, which ever is greater. Surface friction shall not be included in the design unless a friction factor is provided in a geotechnical report signed and sealed by a licensed professional engineer. A safety factor of 1.1 shall be used for buoyancy resistance.

1. Wet well walls shall be designed to withstand lateral earth pressures and static water levels at finished grade as outlined in ACI 350. At a minimum, 3,500 psi concrete shall be used. Class III or IV RCP may be used in lieu of cast in place concrete if structural calculations are provided showing that sufficient strength exists to resist construction and final loadings.

2. Top slabs shall be designed for a uniform loading of 100 pounds per square foot and a point load equal to the weight of the largest pump planned for the lift station at any location. Hatches shall be constructed entirely of aluminum or stainless steel and designed for a minimum of 150-pound-per-square-foot load. The underside of the hatch shall have the following stenciled in red paint: "Warning! Confined Space Entry."

3. Where individual hatches are incorporated into the top slab, the separation distance from inside face to inside face shall be a minimum of 12 inches.

4. Where riser pipes pass through the top slab, offsets or two 45-degree bends shall be used to provide clearance between the outside diameter of the pipe and the inside face of the hatches. The amount of clearance will be determined by the diameter of the slab reinforcing and the maximum aggregate diameter.

6.4 VALVES AND PIPING

6.4.1 General

6.4.1.1 Use of vault-type or above-ground valves and piping is permitted. Valves shall be mounted in a concrete vault, or on an above-ground concrete foundation. Isolation and check valves shall not be located in the wet well.

6.4.1.2 Each pump shall have a separate suction pipe. Suction piping intakes in the wet well shall be fitted with flare 90-degree bends. Eccentric reducers shall be used in suction piping as required. Suction pipe velocity shall be between 3 and 7 feet per second (fps).

6.4.1.3 Force mains shall be a minimum of 4 inches in diameter, unless used in conjunction with grinder pumps. Pump stations with two pumps shall have force main velocities of a minimum of 3 fps with one pump in operation. For pump stations with three or more pumps, the force main velocity shall not be less than 2 fps with the smallest pump only in operation. Force main velocities shall not exceed 6 fps without the engineer performing an analysis for possible high and low negative surge pressures in the event of sudden pump failure.

6.4.1.4 Isolation valves shall be provided on the discharge side of pumps for submersible pumps and suction and discharge side of pumps for dry pit/wet pit lift stations, positioned such that the pump and/or check valve can be isolated for removal. Plug valves, ball valves, gate valves, and pinch valves may be used. Check valves shall be swing type with an external lever and shall be installed in a horizontal position. Use of butterfly valves, tilting disc check valves, or other valves utilizing a tilting disc in the pipe flow is not permitted.

6.4.1.5 Surge relief valves, air release, and/or combination air and vacuum valves shall be provided, as required.

6.4.1.6 Lift station piping shall have flanged or flexible connections to allow for removal of pumps and valves without interruption of the lift station operation.

6.5 PUMPS AND MOTORS

6.5.1 Design requirements for wastewater lift station pumps and motors.

6.5.1.1 Stations with capacities of 100 gallons per minute or greater may be designed with wet well mounted close-coupled type pumps, self-priming pumps, or be wet well/dry well type facilities. Lift stations shall be designed to discharge the peak design flow at the system head required and to operate efficiently during any initial, interim, or ultimate design phase.

6.5.1.2 Firm pumping capacity shall be provided, and is defined as total station, maximum pumping capacity, with the largest pumping unit out of service.

6.5.1.3 Pump selection shall be based on the analysis of the system head and pump capacity curves for the determination of pumping capacities. System losses shall be calculated in accordance with the Hydraulic Institute standards. The selected C coefficient value for use in the calculation of friction head losses per the Hazen-Williams Formula shall be based on the selected pipe material for new and aged (20-year) conditions. Typical values used for design purposes are presented below.

	C Coefficient Value	
Pipe Type	New	20 Years
Ductile Iron (lined)	140	120
Plastic - PVC	140	130

6.5.1.4 Force main velocities shall be included on the system curve.

6.5.1.5 Pumps shall be of a non-clog design, capable of passing a 3-inch diameter or greater incompressible sphere, and shall have suction and discharge openings a minimum of 4 inches in diameter.

6.5.1.6 Pump seals shall be silicon carbide or tungsten carbide.

6.5.2 Pump Operation

6.5.2.1 Electric motors shall be 120-volt single-phase, 240-volt or 480-volt 3-phase.

6.5.2.2 Optimum efficiencies should be considered in the selection of the pumps and motors provided.

6.5.2.3 Leak detection sensors shall be provided in the motor housing of submersible pumps.

6.5.2.4 Motor service factor shall be a minimum of 1.15.

6.5.2.5 Electric motors shall be sized so as to operate at maximum design load without use of the service factor.

6.5.2.6 Thermal protection shall be provided in the motor housing.

6.5.2.7 Electric motors (excluding submersible units) shall be equipped with space heaters.

6.5.3 Pump Installation

6.5.3.1 Pumps shall be securely supported, per manufacturer recommendations, so as to prevent movement or vibration during operation.

6.5.3.2 Rail-type pump support systems shall be provided for submersible pump installations. That allows pump removal and installation without requiring dewatering of or entry into the wet well. Rails, lifting chains, and hardware shall be constructed of Series 300 stainless steel.

6.6 CORROSION PROTECTION AND ODOR CONTROL

6.6.1 Design considerations include corrosion control and protection of concrete and metallic surfaces located within the wet well/valve vault or within the immediate vicinity from the effect of hydrogen sulfide (H_2S) gas in the wastewater. The effects of H_2S gas should be minimized by reducing the production or release of H_2S gas from the wastewater discharging to or being contained in the lift station. Suggested design and control methods include:

6.6.1.1 Protecting the exposed concrete and steel surfaces with acid-resistant materials.

6.6.1.2 The use of Series 300 stainless steel for equipment, piping, devices, etc., exposed to corrosive gases.

6.6.1.3 Providing odor control equipment for wet well atmospheric vents.

6.6.1.4 Design wet wells that lack interior corners, projections, or areas that can result in the accumulation of solids. Design interior surfaces with smooth finishes that facilitate cleaning.

6.6.1.5 Provide washdown water at site when possible.

6.6.2 Surfaces to be protected:

6.6.2.1 Interior of wet well: The Engineer shall specify a plastic liner meeting the requirements of City of Houston Standard Specification Section 02427, entitled "Plastic Liner for Large-Diameter Concrete Sewers and Structures."

6.6.2.2 Piping located within wet well: Exterior-piping surfaces shall be coated with an appropriate painting system selected by the Engineer.

6.6.2.3 Guide rails, lifting chains, hardware, and miscellaneous metal shapes located within wet well shall be constructed/manufactured of Series 300 stainless steel.

6.6.3 Odor Control

6.6.3.1 Engineer shall evaluate the need for odor control and take appropriate steps in the design of the lift station to accommodate the installation of odor control equipment, if required. Engineer shall be the final authority concerning the need for odor control equipment.

6.7 ELECTRICAL CONTROL AND INSTRUMENTATION

6.7.1 General

6.7.1.1 The following electrical control and instrumentation design is recommended for lift stations located within the City of Houston ETJ, where stations are not property of or operated by the City.

6.7.2 Electric Power Requirements

6.7.2.1 The following electrical power sources are the most economical and practical for serving lift stations:

1. For stations where total pump motor sizes do not exceed 30 hp, and where any individual pump motor size does not exceed 20 hp, 120/240-volt, three-phase service is recommended.

2. For stations where individual pump motor sizes do not exceed 5 hp and motor ratings are available as single-phase, and where three-phase service is not available, 120/240 volt, single-phase service may be used.

3. For stations requiring pump motors that are available in only three-phase ratings and where three phase electrical service is not available (or not economically feasible), 120/240-volt, single-phase service with a three-phase inverter unit is acceptable as a last resort but is not recommended. Inverters are available for up to 100-hp motor sizes.

4. For stations where total pump motor sizes exceed 30 hp and where individual motor sizes exceed 20 hp, 480/277-volt, three-phase service is recommended.

5. Where owner has an existing portable generator with only 480/277-volt, three-phase output, it may be more advantageous to utilize 480-volt, three-phase power for the smaller stations.

6. Optional emergency power connections may require a manual transfer switch and generator connector.

6.7.3 Electrical Controls

6.7.3.1 Pump Controller: Solid state, programmable pump controller with pump alternator, submersible level transducer, back-up floats, alarm contacts, and power supply.

6.7.3.2 Controls and Indicators

1. Pump HOA Selector Switch (for each pump)
2. Alarm Reset Switch
3. Seal-Fail and Over-Temp Reset Switch (for each pump protection module - supplied by pump manufacturer)
4. Phase-Fail Light
5. Pump Run Light (for each pump)
6. Control Power Light On
7. Pump Seal-Fail Light (for each pump protection module - supplied by pump manufacturer)
8. Pump Over-Temp Light (for each pump protection module - supplied by pump manufacturer)
9. High Level Alarm Indicator
10. Alarm Rotating Beacon Light
11. Pump Run Elapse Time Meter (for each pump)

6.7.3.3 Motor Protection Devices

1. Motor Circuit Protectors (MCP's) or circuit breakers
2. Motor Overload Current Trip Devices or C.T.'s with Relays (for each motor)
3. Motor Over-Temp and Seal Fail Relays (for each motor - furnished by pump motor manufacturers)
4. Phase Fail Relay

6.7.3.4 Surge Protection Device

1. Lightning and Surge Protection Device installed on Main Power Bus, single- or three-phase, as applicable

6.7.3.5 Level Controls

1. Primary: Solid state transducer with cable and weight, rated for wastewater application

2. Back-up: PVC ball type float with mercury switch - high and low level

6.7.4 Operation

6.7.4.1 As level rises, the submersible level transducer detects the pressure change and sends a 4-20 MA signal that is proportional to wet well level to the pump controller.

1. Each pump is brought on as level rises, and when wet well level falls back to a preset level, all pumps stop.

2. Pump alternator in the controller alternates lead/lag pump selection at end of each pumping cycle.

3. If pumps fail to draw down wet well, high-level alarm signal is initiated at the pump controller and controller automatically switches to standby floats for activation of pump controls.

4. In the event of fail signal from transducer, controller automatically switches to floats.

6.7.4.2 Alarm Signals

1. Alarms activate local indicator lights and send signals to autodialer.

6.7.5 Enclosures

6.7.5.1 Pump Cable Terminal Boxes

1. NEMA 4X stainless steel boxes mounted near pump access hatch for termination of pump power and control cables and for termination of transducer and float cables.

2. All hub-type conduit entries.

6.7.5.2 Control Panel Enclosure

1. NEMA 4X stainless steel enclosure on factory stainless steel stands with inside swing door, back plate, quick release latches, and hooking clasp.

2. All hub-type conduit entries.

6.8 DRAWING REQUIREMENTS

6.8.1 Pump station construction plans shall include drawings that provide the following information:

1. Site layout

2. Plan and profile of pump station and associated site piping

3. Profile view of pump operational and control levels and settings

4. Hydraulic system curve

5. Electrical wiring and control system schematics

6. Structural details

APPENDIX A

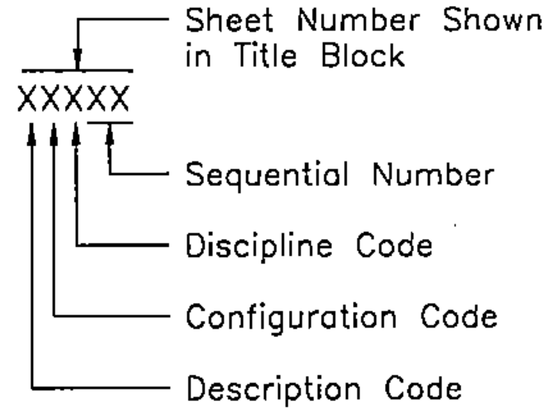
GENERAL DRAWING/FILE INFORMATION

City of Houston
Design Guideline Drawings
For Submersible Lift Stations
Filename & Sheet Numbering Designation Codes

Description Codes

A – 2–Pump Station 100 gpm per Pump
B – 2–Pump Station 100–300 gpm per Pump
C – 2–Pump Station 250–500 gpm per Pump
D – 3–Pump Station 250–2000 gpm per Pump
E – 3–Pump Station 2000–5300 gpm per Pump
F – 4–Pump Station 500–2500 gpm per Pump
G – 5–Pump Station 2 Dry & 3 Wet Weather Pumps
H – 6–Pump Station 2 Dry & 4 Wet Weather Pumps
I – Open
J – Open
K – Open
L – Open
M – Open
N – Open
O – Open
P – Open
Q – Open
R – Open
S – Open
T – Open
U – Open
V – Open
W – Level I Instrumentation
X – Level II Instrumentation
Y – Level III Instrumentation
Z – Common Drawings

Filename Designation



Discipline Codes

A – Architectural
C – Civil
E – Electrical & Instrumentation
G – General
S – Structural

Configuration Codes

0 – Dwg Non–Specific to Configuration
1 – Alternate High Profile Configuration
2 – Preferred Configuration
3 – Alternate Low Profile Configuration

Figure A–1

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
Z0G01	Title Page
Z0A01	Control Building, Architectural
A1C01	Plan View @ Grade & Sections, 2-Pumps @ 100 gpm per Pump, Alternate High Profile Configuration
A1C02	Elevation Sections, 2-Pumps @ 100 gpm per Pump, Alternate High Profile Configuration
A2C01	Plan View @ Grade & Sections, 2-Pumps @ 100 gpm per Pump, Preferred Configuration
A2C02	Elevation Sections, 2-Pumps @ 100 gpm per Pump, Preferred Configuration
A3C01	Plan View @ Grade & Sections, 2-Pumps @ 100 gpm per Pump, Alternate Low Profile Configuration
A3C02	Elevation Sections, 2-Pumps @ 100 gpm per Pump, Alternate Low Profile Configuration
B1C01	Plan View @ Grade & Sections, 2-Pumps @ 100 – 300 gpm per Pump, Alternate High Profile Configuration
B1C02	Elevation Section, 2-Pumps @ 100 – 300 gpm per Pump, Alternate High Profile Configuration
B2C01	Plan View @ Grade & Sections, 2-Pumps @ 100 – 300 gpm per Pump, Preferred Configuration
B2C02	Elevation Section, 2-Pumps @ 100 – 300 gpm per Pump, Preferred Configuration
B3C01	Plan View @ Grade & Sections, 2-Pumps @ 100 – 300 gpm per Pump, Alternate Low Profile Configuration
B3C02	Elevation Section, 2-Pumps @ 100 – 300 gpm per Pump, Alternate Low Profile Configuration
C1C01	Plan View @ Grade & Base Sect, 2-Pumps @ 250 – 500 gpm per Pump, Alternate High Profile Configuration
C1C02	Elevation Section, 2-Pumps @ 250 – 500 gpm per Pump, Alternate High Profile Configuration
C2C01	Plan View @ Grade & Base Sect, 2-Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C2C02	Elevation Section, 2-Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C3C01	Plan View @ Grade & Base Sect, 2-Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
C3C02	Elevation Section, 2-Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
D1C01	Plan View @ Grade & Base Sect, 3-Pumps @ 250 – 2000 gpm per Pump, Alternate High Profile Configuration
D1C02	Elevation Section, 3-Pumps @ 250 – 2000 gpm per Pump, Alternate High Profile Configuration
D2C01	Plan View @ Grade, 3-Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
D2C02	Elevation Section, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D2C03	Base Section, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D3C01	Plan View @ Grade, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3C02	Elevation Section, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3C03	Base Section, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Site Configuration
E1C01	Plan View @ Grade, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E1C02	Elevation Section, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E1C03	Base Section, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E2C01	Plan View @ Grade, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E2C02	Elevation Section, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E2C03	Sections, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E3C01	Plan View @ Grade, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3C02	Elevation Section, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3C03	Base Section, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
F1C01	Plan View @ Grade, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F1C02	Elevation Section, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F1C03	Base Section, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F2C01	Plan View @ Grade, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F2C02	Elevation Section, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F2C03	Base Section, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F3C01	Plan View @ Grade, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3C02	Elevation Section, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3C03	Base Section, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
G1C01	Plan View @ Grade, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G1C02	Elevation Section, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G1C03	Base Section, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
G2C01	Plan View @ Grade, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2C02	Elevation Section, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2C03	Base Section, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2C04	Station Operation Tables, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G3C01	Plan View @ Grade, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3C02	Elevation Section, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3C03	Base Section, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3C04	Station Operation Tables, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H1C01	Plan View @ Grade, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H1C02	Elevation Section, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H1C03	Base Section, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H2C01	Plan View @ Grade, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2C02	Elevation Section, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2C03	Base Section, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2C04	Station Operation Tables, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H3C01	Plan View @ Grade, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3C02	Elevation Section, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3C03	Base Section, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3C04	Station Operation Tables, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
Z0C01	Air Cell Assembly & Details
Z0C02	Typical Details, Civil
Z0C03	Typical Details, Civil
Z0C04	Discharge Piping Support Details
Z0C05	Catwalk Details
Z0C06	Surge Relief Valve Details
Z0C07	Typical Details, Civil
Z0C08	Typical Site Details
Z0C09	Example – Site Plan
A1S01	Structural, 2-Pumps @ 100 gpm per Pump, Alternate High Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
A2S01	Structural, 2–Pumps @ 100 gpm per Pump, Preferred Configuration
A3S01	Structural, 2–Pumps @ 100 gpm per Pump, Alternate Low Profile Configuration
B1S01	Structural, 2–Pumps @ 100 –300 gpm per Pump, Alternate High Profile Configuration
B2S01	Structural, 2–Pumps @ 100 – 300 gpm per Pump, Preferred Configuration
B3S01	Structural, 2–Pumps @ 100 – 300 gpm per Pump, Alternate Low Profile Configuration
C1S01	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Alternate High Profile Configuration
C1S02	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Alternate High Profile Configuration
C2S01	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C2S02	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C2S03	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C3S01	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
C3S02	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
C3S03	Structural, 2–Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
D1S01	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate High Profile Configuration
D1S02	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate High Profile Configuration
D2S01	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D2S02	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D2S03	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D2S04	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D3S01	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3S02	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3S03	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3S04	Structural, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
E1S01	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E1S02	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E1S03	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
E2S01	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E2S02	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E2S03	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E2S04	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E3S01	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3S02	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3S03	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3S04	Structural, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
F1S01	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F1S02	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F1S03	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F2S01	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F2S02	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F2S03	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F2S04	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F3S01	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3S02	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3S03	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3S04	Structural, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
G1S01	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G1S02	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G1S03	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G2S01	Structural, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2S02	Structural, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2S03	Structural, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G2S04	Structural, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G3S01	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3S02	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
G3S03	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3S04	Structural, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H1S01	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H1S02	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H1S03	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H2S01	Structural, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2S02	Structural, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2S03	Structural, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H2S04	Structural, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H3S01	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3S02	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3S03	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3S04	Structural, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
Z0S01	Structural – Typical Details
Z0S02	Structural – General Notes
A1E01	Conduit Layout, 2-Pumps @ 100 gpm per Pump, Alternate High Profile Configuration
A2E01	Conduit Layout, 2-Pumps @ 100 gpm per Pump, Preferred Configuration
A3E01	Conduit Layout, 2-Pumps @ 100 gpm per Pump, Alternate Low Profile Configuration
B1E01	Conduit Layout, 2-Pumps @ 100 – 300 gpm per Pump, Alternate High Profile Configuration
B2E01	Conduit Layout, 2-Pumps @ 100 – 300 gpm per Pump, Preferred Configuration
B3E01	Conduit Layout, 2-Pumps @ 100 – 300 gpm per Pump, Alternate Low Profile Configuration
C1E01	Conduit Layout, 2-Pumps @ 250 – 500 gpm per Pump, Alternate High Profile Configuration
C2E01	Conduit Layout, 2-Pumps @ 250 – 500 gpm per Pump, Preferred Configuration
C3E01	Conduit Layout w/JB Outside Valve Vault, 2-Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration
C3E02	Conduit Layout w/JB Inside Valve Vault, 2-Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
C3E03	Conduit Layout Sections, 2–Pumps @ 250 – 500 gpm per Pump, Alternate Low Profile Site Configuration
D1E01	Conduit Layout, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate High Profile Configuration
D2E01	Conduit Layout, 3–Pumps @ 250 – 2000 gpm per Pump, Preferred Configuration
D3E01	Conduit Layout w/JB Outside Valve Vault, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3E02	Conduit Layout w/JB Inside Valve Vault, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
D3E03	Conduit Layout Sections, 3–Pumps @ 250 – 2000 gpm per Pump, Alternate Low Profile Configuration
E1E01	Conduit Layout, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate High Profile Configuration
E2E01	Conduit Layout, 3–Pumps @ 2000 – 5300 gpm per Pump, Preferred Configuration
E3E01	Conduit Layout w/JB Outside Valve Vault, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuratior
E3E02	Conduit Layout w/JB Inside Valve Vault, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
E3E03	Conduit Layout Sections, 3–Pumps @ 2000 – 5300 gpm per Pump, Alternate Low Profile Configuration
F1E01	Conduit Layout, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate High Profile Configuration
F2E01	Conduit Layout, 4–Pumps @ 500 – 2500 gpm per Pump, Preferred Configuration
F3E01	Conduit Layout w/JB Outside Valve Vault, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3E02	Conduit Layout w/JB Inside Valve Vault, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
F3E03	Conduit Layout Sections, 4–Pumps @ 500 – 2500 gpm per Pump, Alternate Low Profile Configuration
G1E01	Conduit Layout, 3 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
G2E01	Conduit Layout, 3 Wet & 2 Dry Weather Pumps, Preferred Configuration
G3E01	Conduit Layout w/JB Outside Valve Vault, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3E02	Conduit Layout w/JB Inside Valve Vault, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3E03	Conduit Layout Elevations, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3E04	Conduit Layout Sections, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
G3E05	Conduit Layout Sections, 3 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
H1E01	Conduit Layout, 4 Wet & 2 Dry Weather Pumps, Alternate High Profile Configuration
H2E01	Conduit Layout, 4 Wet & 2 Dry Weather Pumps, Preferred Configuration
H3E01	Conduit Layout w/JB Outside Valve Vault, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3E02	Conduit Layout w/JB Inside Valve Vault, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3E03	Conduit Layout Elevations, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3E04	Conduit Layout Sections, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
H3E05	Conduit Layout Sections, 4 Wet & 2 Dry Weather Pumps, Alternate Low Profile Configuration
W0E01	Level I Instrumentation, Outdoor Control Cabinet Installation & Air Piping Schematic
W0E02	Level I Instrumentation, Outdoor Control Panel Equipment Layout & Schedule
W0E10	Level I Instrumentation, Single Phase, Control Cabinet Equipment Layout
W0E11	Level I Instrumentation, Single Phase, Control Cabinet Equipment Layout
W0E12	Level I Instrumentation, Single Phase, Single Line, & Power Wiring Diagrams
W0E13	Level I Instrumentation, Single Phase, Control Wiring Diagram
W0E14	Level I Instrumentation, Single Phase, Control Wiring Diagram
W0E15	Level I Instrumentation, Single Phase, Alternate Control Wiring Diagram
W0E20	Level I Instrumentation, Three Phase, Control Cabinet Equipment Layout
W0E21	Level I Instrumentation, Three Phase, Control Cabinet Equipment Layout
W0E22	Level I Instrumentation, Three Phase, Single Line, & Power Wiring Diagrams
W0E23	Level I Instrumentation, Three Phase, Control Wiring Diagram
W0E24	Level I Instrumentation, Three Phase, Control Wiring Diagram
W0E25	Level I Instrumentation, Three Phase, Alternate Control Wiring Diagram
W0E30	Level I Instrumentation, Control System Process & Instrumentation Diagram
X0E01	Level II Instrumentation, Outdoor Control Cabinet Installation & Air Piping Schematic
X0E02	Level II Instrumentation, Outdoor Control Cabinet Equipment Layout & Schedule
X0E03	Level II Instrumentation, Outdoor Control Cabinet Equipment Layout
X0E04	Level II Instrumentation, Outdoor Control Cabinet Equipment Layout
X0E05	Level II Instrumentation, Outdoor Control Cabinet Equipment Layout

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
X0E06	Level II Instrumentation, Outdoor Panel, Power Wiring Diagram
X0E10	Level II Instrumentation, Outdoor Power Panel, Single Line Diagram
X0E21	Level II Instrumentation, Indoor Control Cabinet Layout & Air Piping Schematic
X0E22	Level II Instrumentation, Indoor Control Cabinet Equipment Layout
X0E23	Level II Instrumentation, Indoor Control Cabinet Equipment Layout
X0E24	Not Used
X0E25	Level II Instrumentation, Indoor Panel, MCC Power Schematic & Wiring Diagram
X0E28	Level II Instrumentation, Indoor Panel, Single Line Diagram
X0E40	Level II Instrumentation, Outdoor Panel, Control System Process & Instrumentation Diagram
X0E41	Level II Instrumentation, Outdoor Panel, Control System Process & Instrumentation Diagram
X0E50	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E51	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E52	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E53	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E54	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E55	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E56	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E57	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E58	Level II Instrumentation, Outdoor Control Panel, Control Wiring Diagram
X0E60	Level II Instrumentation, Indoor Panel, Control System Process & Instrumentation Diagram
X0E61	Level II Instrumentation, Indoor Panel, Control System Process & Instrumentation Diagram
X0E70	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E71	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E72	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E73	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E74	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E75	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E76	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
X0E77	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
X0E78	Level II Instrumentation, Indoor Control Panel, Control Wiring Diagram
Y0E20	Level III Instrumentation, Air Piping Schematic
Y0E21	Level III Instrumentation, Control Cabinet Layout & Equipment Schedule
Y0E22	Level III Instrumentation, Control Cabinet Equipment Layout
Y0E23	Level III Instrumentation, Control Cabinet Equipment Layout
Y0E24	Not Used
Y0E25	Not Used
Y0E26	Level III Instrumentation, MCC Power Schematic, Control Power & Communications Wiring Diagram
Y0E30	Level III Instrumentation, Single Line Diagram
Y0E40	Level III Instrumentation, Control System Process & Instrumentation Diagram
Y0E41	Level III Instrumentation, Control System Process & Instrumentation Diagram
Y0E50	Level III Instrumentation, Control Wiring Diagram
Y0E51	Level III Instrumentation, Control Wiring Diagram
Y0E52	Level III Instrumentation, Control Wiring Diagram
Y0E53	Level III Instrumentation, Control Wiring Diagram
Y0E54	Level III Instrumentation, Control Wiring Diagram
Y0E55	Level III Instrumentation, Control Wiring Diagram
Y0E56	Level III Instrumentation, Control Wiring Diagram
Y0E57	Level III Instrumentation, Control Wiring Diagram
Y0E58	Level III Instrumentation, Control Wiring Diagram
Y0E59	Level III Instrumentation, Control Wiring Diagram
Y0E60	Level III Instrumentation, Control Wiring Diagram
Z0E01	Electrical Symbols, Legend, Lighting Fixture Symbols & Abbreviations
Z0E02	Typical Junction Box Details
Z0E03	Typical Details, Instrumentation/Electrical
Z0E04	Typical Details, Instrumentation/Electrical
Z0E05	Control Building, Instrumentation/Electrical
Z0E06	Example – Electrical Site Plan

DRAWING INDEX
COH DESIGN GUIDELINES FOR SUBMERSIBLE STATIONS

New Sht No.	Drawing Title
Z0E10	Level II or III Instrumentation, MCC Elevations
Z0E11	Level II or III Instrumentation, MCC Elevations
Z0E12	Level II or III Instrumentation, MCC Elevations
Z0E13	Level II or III Instrumentation, MCC Elevations
Z0E14	Level II or III Instrumentation, MCC Elevations
Z0E15	Level II or III Instrumentation, MCC Elevations
Z0E20	Level II or III Instrumentation, Conduit Schedules for 240V System
Z0E21	Level II or III Instrumentation, Conduit Schedules for 480V System
Z0E40	Level II or III Instrumentation, Device Ratings Schedules for 240V System
Z0E41	Level II or III Instrumentation, Device Ratings Schedules for 480V System
Z0E42	Level II or III Instrumentation, Device Ratings Schedules for 480V System
Z0E43	Level II or III Instrumentation, Device Ratings Schedules for 480V System
Z0E44	Level II or III Instrumentation, Device Ratings Schedules for 480V System

City of Houston Standard Drawings - CADD File Layering (Level) Breakdown

All Text and Text related line entitles (i.e, Dimension & Leader Lines, Cross Section Lines, etc.) are placed on the layers beginning with 'T'; and each entity is placed on the layer corresponding to its color.

Example:

Layer Name	Color	Linetype	Description
TXT-1	1 (red)	Continuous	Text, Dim & Ldr lines which are red
TXT-2	2 (yellow)	Continuous	Text, Dim & Ldr lines which are yellow
TXT-3	3 (green)	Continuous	Text, Dim & Ldr lines which are green
TXT-4	4 (cyan)	Continuous	Text, Dim & Ldr lines which are cyan

All Other entities are placed on layers beginning with 'L'; and each entity is placed on the layer corresponding to its color and linetype.

Example:

Layer Name	Color	Linetype	Description
LCON-1	1 (red)	Continuous	Other entities which are Red & Continuous Lines
LCON-2	2 (yellow)	Continuous	Other entities which are Yellow & Continuous Lines
LCON-3	3 (green)	Continuous	Other entities which are Green & Continuous Lines
LCON-4	4 (cyan)	Continuous	Other entities which are Cyan & Continuous Lines
LCTR-1	1 (red)	Center	Other entities which are Red & Center Lines
LCTR-2	2 (yellow)	Center	Other entities which are Yellow & Center Lines
LCTR-3	3 (green)	Center	Other entities which are Green & Center Lines
LCTR-4	4 (cyan)	Center	Other entities which are Cyan & Center Lines
LDAS-1	1 (red)	Dashed	Other entities which are Red & Dashed Lines
LDAS-2	2 (yellow)	Dashed	Other entities which are Yellow & Dashed Lines
LDAS-3	3 (green)	Dashed	Other entities which are Green & Dashed Lines
LDAS-4	4 (cyan)	Dashed	Other entities which are Cyan & Dashed Lines
LHID-1	1 (red)	Hidden	Other entities which are Red & Hidden Lines
LHID-2	2 (yellow)	Hidden	Other entities which are Yellow & Hidden Lines
LHID-3	3 (green)	Hidden	Other entities which are Green & Hidden Lines
LHID-4	4 (cyan)	Hidden	Other entities which are Cyan & Hidden Lines

Other layers or levels may exist; i.e. LMHID-4, LSDAS-1, etc. The last digit represents the color no. & the digits between L and the last digit represent the entity linetype. Unused layers have been purged from the drawing file.

Suggested Color to Line Weights

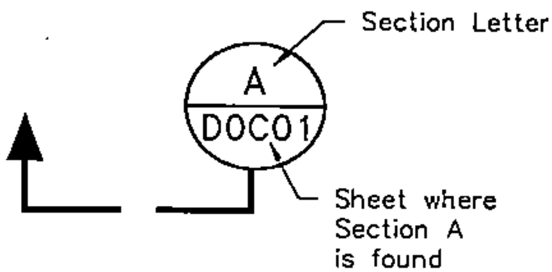
Color	Line Weight
1 (red)	0.35 mm
2 (yellow)	0.50 mm
3 (green)	0.70 mm
4 (cyan)	0.25 mm
5 (blue)	0.25 mm
6 (magenta)	0.35 mm
7 (white)	0.50 mm
8 (grey)	0.35 mm
9 (rust)	0.35 mm
10 (gold)	0.25 mm
11 (avocado)	0.25 mm

Figure A-3

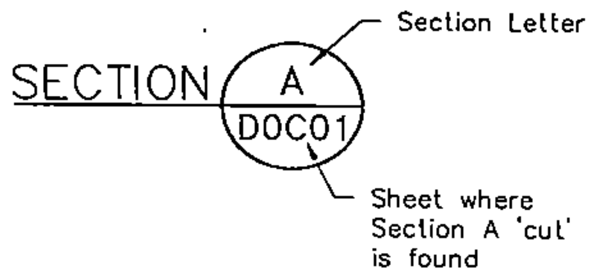
EXPLANATION OF SECTION & DETAIL INDICATORS FOR COH LIFT STATION DESIGN GUIDELINE DRAWINGS

Section Indicators

Indicator on Field of Dwg ('Cut'):

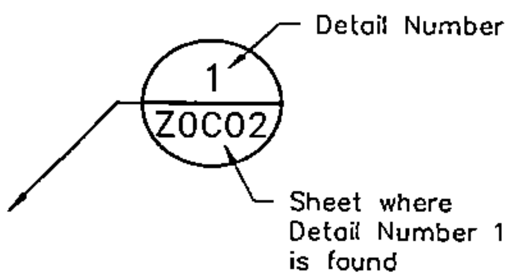


Indicator at Section:

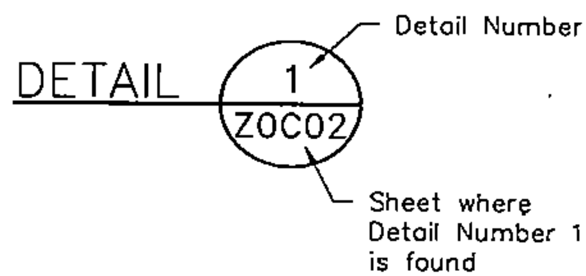


Detail Indicators

Indicator on Field of Dwg (Callout):



Indicator at Detail:

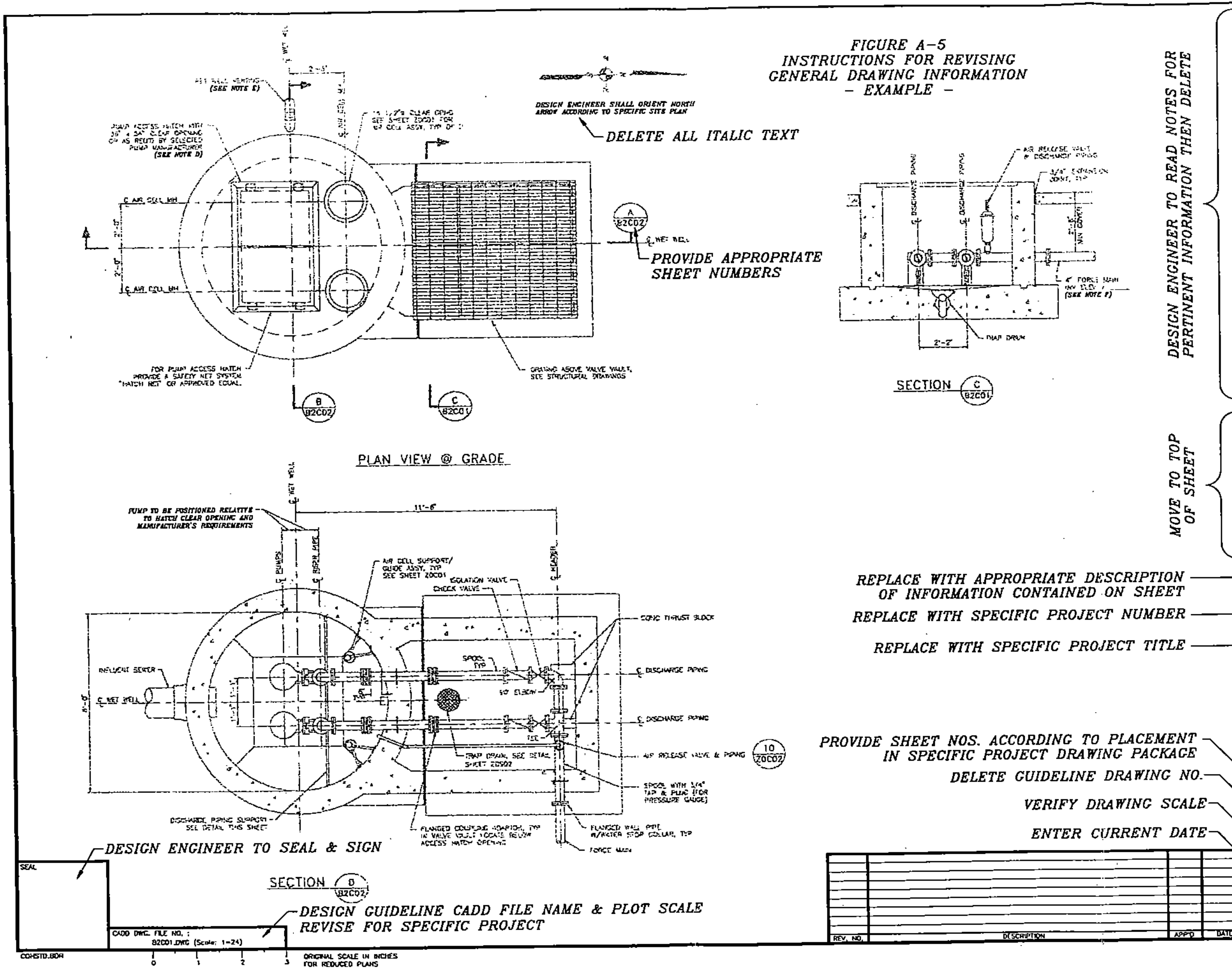


Note:
Details are not referenced back to the sheet(s) where they are called out on the Field of Dwg. These references would be numerous, and locations redundant in relation to each separate lift station configuration.

Notes:
The sheet number is located in the lower right corner of the drawing Title Block in the space labeled "DWG NO."
The sheet numbers called out on the Design Guideline Drawings are for the purposes of referencing information in the Design Guideline Drawing package. The Design Engineer shall revise <u>all</u> sheet number references to reflect the appropriate sheet number in his project drawing package.

Figure A—4

FIGURE A-5
INSTRUCTIONS FOR REVISING GENERAL DRAWING INFORMATION
- EXAMPLE -



NOTES TO DESIGN ENGINEER:

A. THESE LIFT STATION DRAWINGS ARE CONSIDERED TO BE DESIGN GUIDELINES FOR THE CONSTRUCTION OF CITY OF HOUSTON WASTEWATER SUBMERSIBLE LIFT STATIONS. THEIR INTENDED USE IS AS A FRAMEWORK FOR THE CONTRACTED DESIGN ENGINEER IN DEVELOPING SPECIFIC LIFT STATION DESIGNS.

IT IS THE RESPONSIBILITY OF THE CONTRACTED DESIGN ENGINEER TO VERIFY THE COMPLETENESS AND ACCURACY OF THE INFORMATION HEREIN CONTAINED AND TO ADJUST ACCORDING TO SPECIFIC SITE REQUIREMENTS.

B. THIS DESIGN IS BASED UPON THE LARGEST CAPACITY PUMP FOR THIS STANDARD (RANGE: 100 - 300 GPM PER PUMP)

C. LIFT STATION DESIGN IS BASED UPON NOMINAL 4" PUMP, VALVES AND PIPING AS THE SIZES RECOMMENDED FOR THIS STANDARD STATION. THE DESIGN WILL ACCOMMODATE NOMINAL 6" PUMP, VALVES AND PIPING IF SPECIFIC SITE CONDITIONS REQUIRE.

D. DESIGN ENGINEER TO VERIFY THE SIZE AND LOCATION OF THE WET WELL HATCHES ACCORDING TO THE SELECTED PUMP AND HATCH MANUFACTURERS' REQUIREMENTS.

E. THE ACTUAL LOCATION OF THE WET WELL VENTING MAY VARY ACCORDING TO SITE REQUIREMENTS. WHERE POSSIBLE, LOCATE ON THE NORTHWEST SIDE OF THE WET WELL.

F. ELEVATIONS AND INFORMATION OMITTED ARE DETERMINED BY DESIGN ENGINEER PER SPECIFIC SITE REQUIREMENTS.

G. SEE DETAIL AND STRUCTURAL DRAWINGS FOR DIMENSIONS AND INFORMATION NOT SHOWN.

H. THE DESIGN ENGINEER SHALL INCORPORATE ONLY THE NECESSARY STANDARD GUIDELINE DRAWINGS AND DETAILS INTO HIS PROJECT CONTRACT DOCUMENTATION PACKAGE, AND SHALL ADJUST PAGE NUMBERS AND CROSS REFERENCING ACCORDINGLY.

I. THE DESIGN ENGINEER SHALL CONSULT THE CITY OF HOUSTON DESIGN GUIDELINES MANUAL, THE ENGINEERING DESIGN MANUAL, AND THE MASTER SPECIFICATIONS FOR FURTHER INSTRUCTIONS AND INFORMATION PERTINENT TO THESE STANDARD DESIGN GUIDELINE DRAWINGS.

J. THE DESIGN ENGINEER SHALL REMOVE THESE NOTES, ALL REFERENCES TO THESE NOTES, AND ANY OTHER EXTRANEOUS INFORMATION FROM THE DESIGN GUIDELINE DRAWINGS. DESIGN ENGINEER SHALL PROVIDE ANY NOTES OR OTHER APPROPRIATE INFORMATION NECESSARY TO COMPLETE THE LIFT STATION DESIGN.

NOTES:

1. SEE DETAIL AND STRUCTURAL DRAWINGS FOR DIMENSIONS AND INFORMATION NOT SHOWN.
2. CONTRACTOR TO CONFIRM SIZE AND LOCATION OF THE WET WELL HATCHES PER SELECTED HATCH AND PUMP MANUFACTURERS' REQUIREMENTS.

PROVIDE ADDITIONAL NOTES AS REQUIRED

PLAN VIEW @ GRADE & SECTIONS
2 PUMPS @ 100 - 300 GPM PER PUMP
LOW PROFILE, SECURED SITE CONFIGURATION

PROJECT NO. R-0267-02-2

TITLE CITY OF HOUSTON DESIGN GUIDELINE DRAWINGS FOR SUBMERSIBLE LIFT STATIONS

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING
ENGINEERING, CONSTRUCTION AND REAL ESTATE GROUP

APPROVALS

WATER DESIGN	TRAFFIC AND SIGNAL DESIGN
STORM SEWER DESIGN	STREET, BRIDGE & R.O.W.
WASTEWATER DESIGN	CONSTRUCTION
OTHER REVIEWS	
PLANNING AND DEVELOPMENT	
CITY ENGINEER	DATE

SCALE: 1/2" = 1'-0"	DESIGNED BY:
SUBMITTED:	DRAWN BY:
DATE: DECEMBER, 1995	SHEET NO. of SHEETS
SURVEY BY:	DWG. NO. B2C01
FIELD BOOK NO.	

APPENDIX B

STRUCTURAL DESIGN CALCULATIONS

STRUCTURAL DESIGN CALCULATIONS

Introduction:

The Design Engineer shall consult the City of Houston Design Guidelines Manual, the Engineering Design Manual and the Master Specifications for performing Structural Design Calculations.

Attached Structural Design Calculations were in conformity with the Engineering Design Manual for standard submersible lift stations. The Design Engineer shall revise or adjust these calculations to meet project specific requirements. These calculations shall be part of the Structural Design Calculations for a specific project.

STRUCTURAL DESIGN CALCULATIONS

INDEX

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON			JOB NO: 3904-00 0101
SUBJECT: 2-PUMP LIFT STATION			SHEET: 11
DESIGNED: NMP	DATE: 1-6-95	CHECKED:	DATE:

"CAISSON CONSTRUCTION" of Wetwell: Alternate Method : Precast Concrete Design & Construction

The contractor, at his option, may select to utilize precast concrete units for "Caisson Construction" method. He will confirm to the City of Houston Engineering Manual for standard Pump Station Design, Section 3 - Structural Design Criteria and the following requirements:

1. Precast concrete design calculations and drawings shall be prepared under the supervision of and sealed by an engineer registered in the State of Texas.
2. Precast units shall be designed to resist lateral pressure due to tilting during sinking.
3. Connections between units shall be designed to transfer shear due to tilting and tension due to hang-up forces due to adhesion/friction between caisson wall and adjacent soil.
4. All joints between precast units shall be watertight.
5. All costs related to alternate method shall be at the contractor's expense.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, Tx, stds		JOB NO: 3921-00 0101
	SUBJECT: Baffle wall at B/WetWell		SHEET: 1 of 1
	DESIGNED: NMP	DATE: 11-20-95	CHECKED:	DATE:

8 inch thick Baffle wall w/ Port holes in bottom:

Assume. 2–6" x 1'-0 to 1'-6" wide opngs.

Differential water depth
If port holes get blocked.

$h_w = 4'$ max.

$M = \frac{0.063 \times 4^3}{6} = 0.7$ k/ft $\quad M_u = 1.5$ k/ft

$V = 0.063 \times 4^2/2 = 0.5$ k/ft $\quad V_u = 0.85$ k/ft

$t = 8"$ wall

$d = 4" \quad F = 0.016 \quad$ Assume 50% wall remain w/ port holes.

$K_n = \frac{1.5 \times 2}{0.016} = 188$

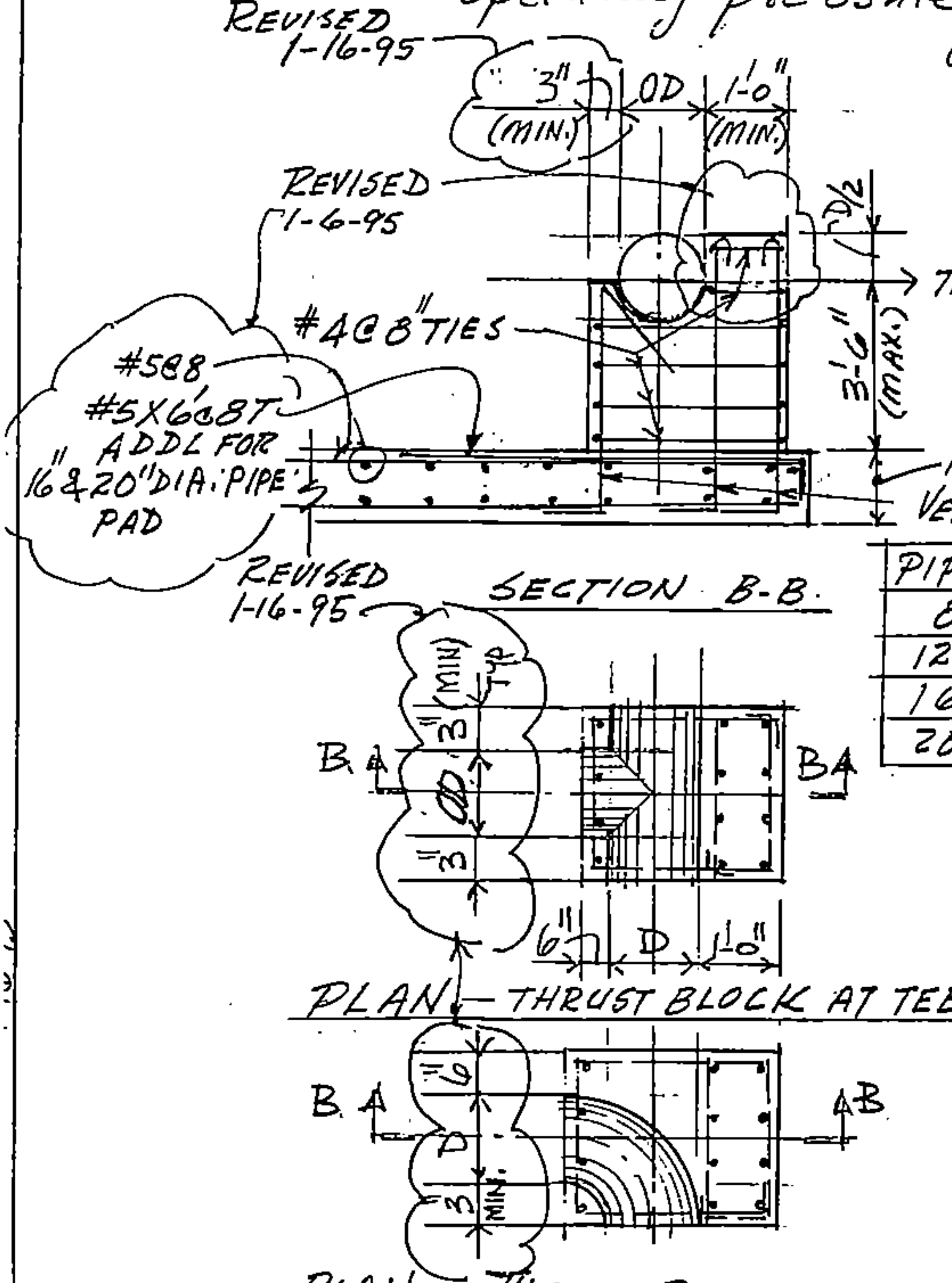
$\rho = 0.0036 \quad A_s = 0.17$ in²/ft $\quad$ #4@12 Vert

#4@12 Hori.
in mid thickness of 8" wall.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT City of Houston			JOB NO. 3904-00 0101
SUBJECT Thrust Blocks			SHEET 10
DESIGNED NMP	DATE 1-5-95	CHECKED	DATE

Thrust blocks; For 8", 12" 16" and 20" ID PIPE with Operating pressure 50psi (max). (115 ft Head).



PIPE DIA.	No. OF VERT BARS
8"	3-2 #5
12"	3-3 #5
16"	3-4 #5
20"	3-4 #5

Pat - Please Delete Pipe thrust block shown on S-22 and Add above details instead -

CONNECTIONS

Table 6.20.8 Shear strength of welded headed studs

I—Design shear strength limited by concrete:

Use smaller of the values from Eqs. 6.5.8a and 6.5.9

$\phi V_c = (\phi 628 d_b^2 \lambda \sqrt{f'_c})n$ (Eq. 6.5.8a) for $d_e > 15 d_b$

Table A gives values for n = 1, ϕ = 0.85

$\phi V_c = \phi V'_c C_w C_t C_c$ (Eq. 6.5.9) for $d_e < 15 d_b$

where:

$\phi V'_c = \phi 12.5 d_e^{1.5} \lambda \sqrt{f'_c}$

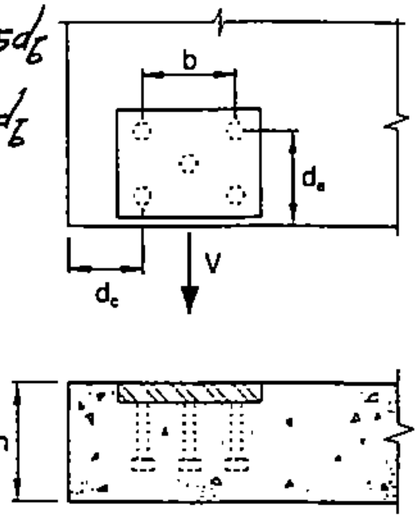
$$C_w = \left(1 + \frac{b}{3.5 d_e}\right) \le n_s$$

$$C_t = \frac{h}{1.3 d_e} \le 1.0$$

$$C_c = \left[0.4 + 0.7\left(\frac{d_c}{d_e}\right)\right] \le 1.0$$

Table B gives values for ϕ = 0.85

where: n_s = number of studs in back row; see figure for other notation



II—Design shear strength limited by steel:

$\phi V_s = (\phi 35{,}344 d_b^2)n$ (Eq. 6.5.14a) $f_s = 60$ ksi

Table C gives value for n = 1, ϕ = 1.0

$35{,}344 = 0.75 \times 60{,}000 \times \frac{\pi}{4}$

Table A—ϕV_{cr}, kips

f'_c, psi	4000		5000		6000		7000		8000	
d_b, in. \ λ	1.0	0.85	1.0	0.85	1.0	0.85	1.0	0.85	1.0	0.85
¼	2.15	1.83	2.40	2.04	2.63	2.24	2.85	2.42	3.04	2.58
⅜	4.74	4.03	5.30	4.51	5.81	4.94	6.28	5.33	6.71	5.70
½	8.43	7.16	9.45	8.03	10.32	8.78	11.15	9.48	11.82	10.13
⅝	13.19	11.21	14.72	11.79	16.15	13.72	17.44	14.83	18.65	15.85
¾	19.00	16.14	21.23	18.04	23.26	19.77	25.12	21.35	26.85	22.82
⅞	25.85	21.97	28.90	24.56	31.66	26.91	34.19	26.09	36.55	31.07

Table B—$\phi V'_c$, kips

d_e, in. \ λ	1.0	0.85	1.0	0.85	1.0	0.85	1.0	0.85	1.0	0.85
2	1.90	1.62	2.12	1.81	1.77	1.51	2.51	2.14	2.69	2.29
3	3.49	2.97	3.90	3.31	4.26	3.63	4.62	3.82	4.94	4.20
4	6.38	4.57	6.00	5.11	6.58	5.59	7.11	6.04	7.60	6.46
5	7.51	6.38	8.39	7.14	9.19	7.82	9.94	8.45	10.62	9.03
6	9.88	8.40	11.04	9.39	12.09	10.29	13.08	11.11	13.97	11.87
7	12.45	10.98	13.80	11.82	15.24	12.95	16.46	13.99	17.60	14.96
8	15.20	12.82	16.99	14.44	18.61	15.81	16.44	17.08	21.50	18.27
9	18.14	15.44	20.28	17.24	22.21	18.88	23.99	20.40	25.65	21.80
10	21.25	18.06	23.75	20.18	26.01	22.11	18.10	23.88	30.04	25.53
11	24.52	20.84	27.41	23.30	30.03	25.52	32.43	27.57	34.67	29.47
12	27.94	23.74	31.22	26.53	34.20	29.07	36.94	31.40	39.49	33.67

Table C—ϕV_s, kips

Diameter, in.	¼	⅜	½	⅝	¾	⅞
ϕV_s	2.2	5.0	8.8	13.8	19.9	27.1

$f_s = 60$ ksi

Ref1

6.5 DESIGN FOR WALL MOMENT STRENGTH

For structural walls in moderate height buildings, walls of uniform cross section with uniformly distributed vertical and horizontal reinforcement are usually the most economical. Concentration of reinforcement at the extreme ends of a wall (or wall segment) is usually not required for walls in moderate height buildings. Uniform distribution of the vertical wall reinforcement, as required for shear, will usually suffice for required moment strength. Also, minimum amount of reinforcement will usually be sufficient, not only for shear strength, but also for moment strength. Moment strength of a rectangular wall section containing uniformly distributed vertical reinforcement and subjected to combined moment and axial load can be easily calculated by:[6.1]

$$\boxed{\varphi M_n = \varphi\left[0.5A_{st}f_y\ell_w\left(1 + \frac{P_u}{A_{st}f_y}\right)\left(1 - \frac{c}{\ell_w}\right)\right]}$$

where A_{st} = total area of vertical wall reinforcement

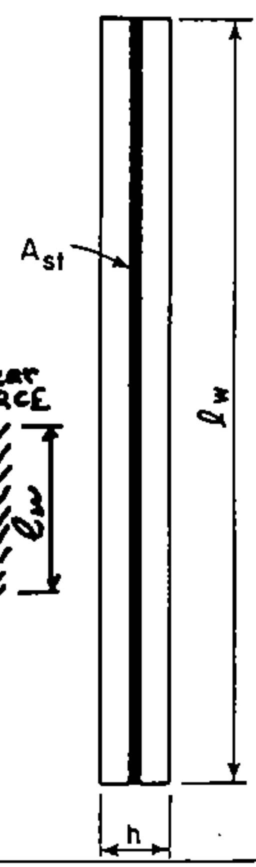
$= A_b\ell_w/s$

ℓ_w = horizontal (Vertical) length of wall

s = spacing of vertical wall reinforcement

A_b = area of each bar (Vert.) OR (Horiz).

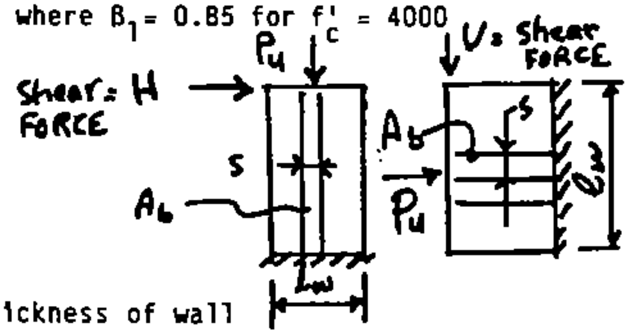
P_u = factored axial compressive load



$\frac{c}{\ell_w} = \frac{\omega + \alpha}{2\omega + 0.85\beta_1}$, where $\beta_1 = 0.85$ for $f'_c = 4000$

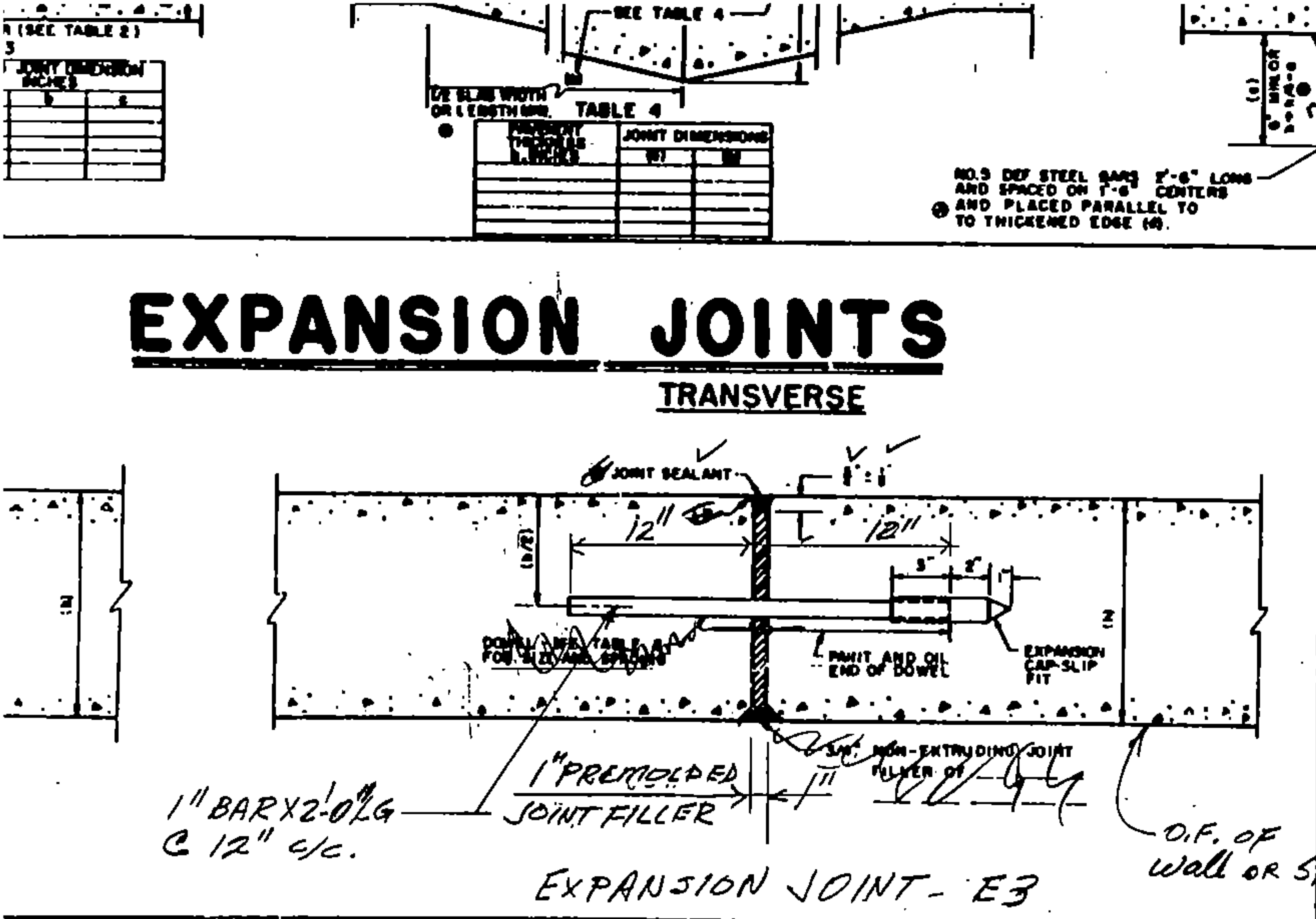
$\omega = \left(\frac{A_{st}}{\ell_w h}\right)\frac{f_y}{f'_c}$

$\alpha = \frac{P_u}{\ell_w h f'_c}$



h = overall thickness of wall

φ = 0.90 (strength primarily controlled by flexure with low axial load.)



REF: U/S Depts of Army and Air Force
TM 5-824.3
AFM 88-6 Chpt. 3.
"Rigid PVMTS For Airfields other than Army."

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, TX, 5TDS LP, SSC Pump Stn A.2		JOB NO. 3921-00 0101
	SUBJECT: 2 Pumps – 100 GPM/Pump		SHEET 1 of 2
	DESIGNED: NMP	DATE: 12-14-95	CHECKED	DATE

Wet Well: "Precast Concrete Units installed by "Caisson-Sinking Method"

Max. depth = 30'-0"
Wall t = 8" (nominal).

Consider half ($\frac{1}{2}$) depth gets suspended.

Hang-up force $= 0.50 \times 30' \times 0.67 \times 0.150 = 1.50^{k}/ft$ of perimeter

provide Six Connections (min.) per Joint

V = pull-out Force per Connection

$= \dfrac{\pi \times 6.67 \times 1.50}{6} = 5.3^{k}$

$V_u = 1.4 \times 5.3 = 7.42^{k}$

Ref: PCI Design HandBook, 4th Ed. table 6.20.8

$d_e = 4$ in. (min). $< 15 d_b = 7.5"$

$d_c = \dfrac{\pi \times 72}{6 \times 2} \cong 18"$

$d_b = \frac{1}{2}"$ Dia Studs

$b = 6"$ assume $h = \frac{2}{3} \times t = 5.36"$

$\phi V_c = 8.43^{k} \times 2 = 16.86^{k}$

$\phi V_s = 8.8^{k} \times 2 = 17.6^{k}$

or $\phi V_c = \phi V_c' C_w C_t C_c$ where $\phi V_c' = 6.38$

$= 1.43 \times 6.38$

$\phi V_c = 9.12^{k} > V_u = 7.42$

$C_w = \left(1 + \dfrac{b}{3.5 d_e}\right) = 1.43 < n_s = 2$

$C_t = \dfrac{h}{1.3 d_e} = 1.03$ $\Big\}$ 1.00

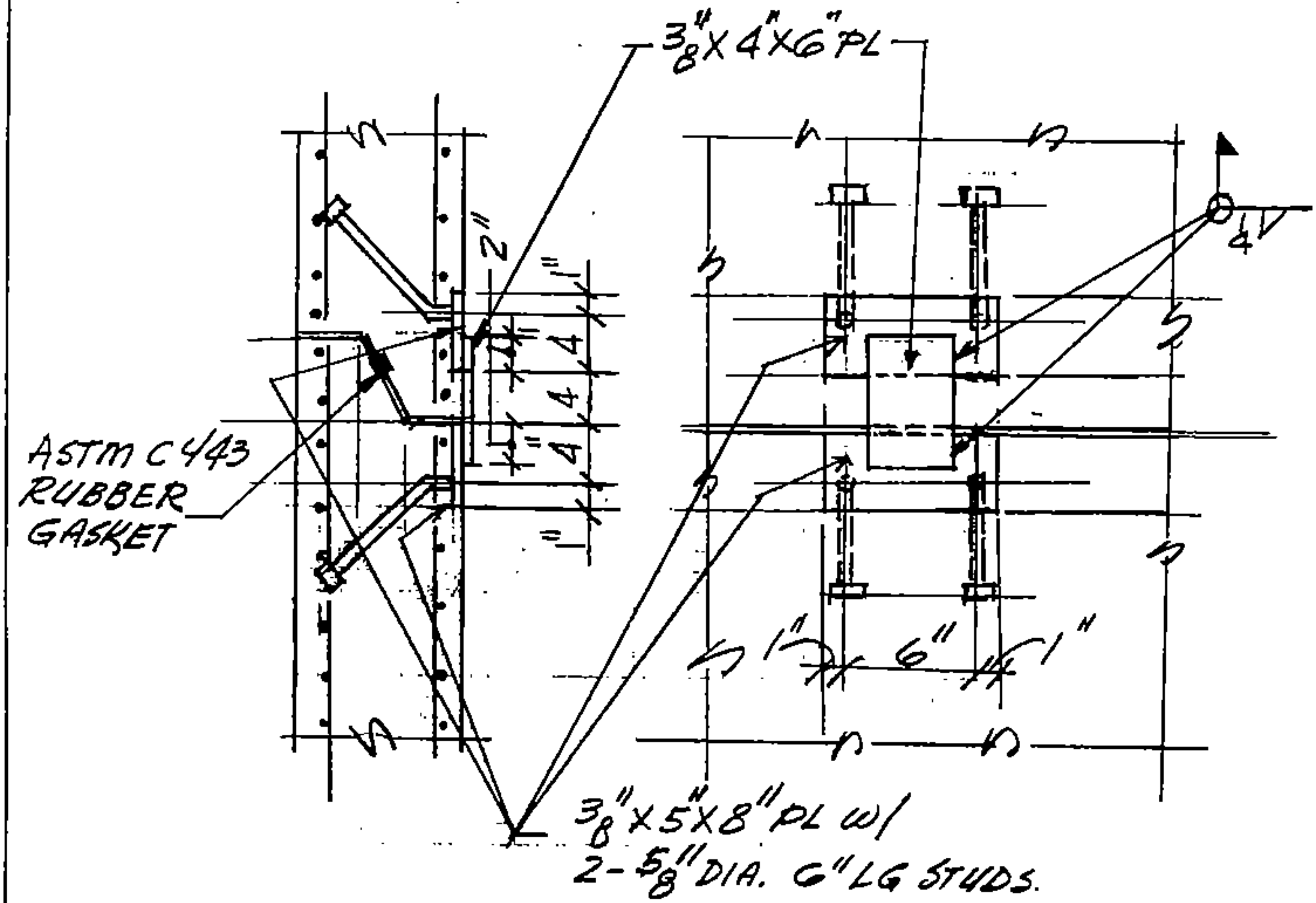
$C_c = 0.4 + 0.7\left(\dfrac{18}{4}\right) = 3.55 < 1.00$

for $\frac{5}{8}"\phi$ Studs
$\phi V_c = 9.12^{k}$

$\frac{3}{8}" \times 4"$ Weld PL, $T = \frac{3}{8} \times 4 \times 24 = 36^{k}$

$\frac{1}{4}"$ Fillet Weld, $T_{weld} = \frac{1}{4} \times 6 \times 24 = 36^{k}$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX, STDS		JOB NO. 3971-00 0101
	SUBJECT: 2 PUMPS - 100 GPM/PUMP		SHEET 2 OF 2
	DESIGNED: NMP	DATE: 12-14-95	CHECKED	DATE



Precast Units Connection Details, Caisson Construction Method.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT CITY OF HOUSTON			JOB NO. 3904.00 0101
	SUBJECT Lift Station : 2 pumps 100 - 300 GPM/Each.			SHEET 1
	DESIGNED NMP	DATE 12-6-94	CHECKED ABG	DATE 1-3-95

Wet Well:

Inside diameter = 8'-0"

$t = 12"$, Outside diameter = 10'-0" (ASTM C361, 102" w/ t = 9")

$t = 12\frac{1}{2}"$, " " = 10'-1" (ASTM C76, 102" w/ t = 9½")

$t = 13\frac{1}{4}"$, " " = 10'-2½" (" " 102" w/ t = 10¼")

Max. depth = 30 feet in Ground.

Design Lateral pressure = 105 psf/ft depth with surcharge lateral pressure of 100 psf for full depth.

"Sinking Caisson" method:

1. Caisson at Final position. Inside water maintained to full depth, with full excavation inside completed.
   Net lateral pressure, $p = (105 - 63) = 42$ psf/ft
2. Base Slab, "tremie" method completed and cured. Inside dewatered
   Net Lateral pressure, $p = 105$ psf/ft
3. Top Slab in place
   Net Lateral pressure $p = 100$ psf + 105 psf/ft.

Ref: 1. ACI 318 and ACI 350 R.
2. Structural Analysis of Shells, Baker, Kovaleski, Rish
3. Circular Concrete tanks w/o prestressing, PCA Bulletin ST-57 (IS0 72.01D).
4. Formulas for Stress and Strain, Roark & Young

$f'_c = 4{,}000$ psi. Conc. at 28 days

$f_y = 60{,}000$ psi Reinf. ASTM A615 Gr. 60.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.				
PROJECT: CITY OF HOUSTON				JOB NO. 3904.00 0101
SUBJECT: Lift Stn : 2 Pumps 100-300 GPM ea.				SHEET 2
DESIGNED: WMP	DATE: 12.8-94	CHECKED: [signature]		DATE: 1-4-95

Case I: Consider Cylindrical Shell fixed at base and free at top with linear external lateral load.

REF: STRUC. ANALYSIS OF SHELLS

$K = \dfrac{\sqrt[4]{3(1-\mu^2)}}{\sqrt{Rt}}$ $\quad \mu = 0.20$

$R = 4$ ft

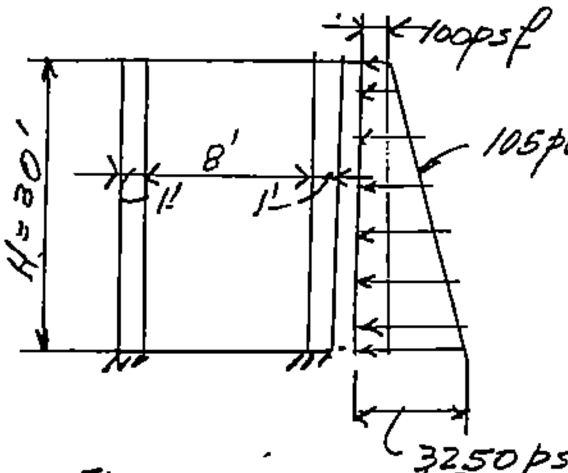
$= \dfrac{1.3027}{2} = 0.6514$ $\quad t = 1.$ wall

$L = H = 30$ ft.

$KL = 19.54$

$\lambda_t P_V = 100$ psf

$P_V = 3250 - 100 = 3150$ psf



$\lambda_p = \dfrac{100}{3150} = \underline{0.032}$

Fig 5-13 (Fixed Base) $\bar{M} = 0.005 \times 3.10 \times 30^2 = 14.0$ k-ft/ft (0.0025 CONSERVATIVE) Fixed (Tension O.F.)

$d = 12.5'' - 2.5'' - \frac{1}{2} = 9.5''$ $\quad F = 0.09$

$M_{u_{des}} = 1.3 \times 1.7 \times 14 = 31^k$

$K_n = 344$ $\quad \rho = 0.0068$

$A_s = 0.78$ in²/ft $\quad$ #6@6" Vert. O.F. (0.88 in²/ft)

$\Sigma A_s = 0.78 + 0.05 = 0.83$ in²/ft

FROM UNEVEN SINKING. SHT. 4.

Fig. 5.9:

$M_{max} = 0.001 \times 3.10 \times 30^2 = 3^k$

$M_{u_{des}} = 1.3 \times 1.7 \times 3 = 6.6$ k/ft

$K_n = 74.$ $\quad \rho = 0.0014$

$\rho_{min} = .0033.$

$A_s = 0.38$ in² $\quad$ <u>#6@12 Vert. I.F.</u>

Fig 5.11:

$V_{max} = 0.04 \times 3.10 \times 30' = 3.72$ k/ft

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 12 \times 9.5 = 12.26$ k/ft

$V_u = 3.72 \times 1.7 = 6.32^k <$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0101
	SUBJECT: Lift Stns 2 pumps 100-300 GPM each			SHEET 3
	DESIGNED: MMP	DATE: 12.8.94	CHECKED: AAG	DATE: 1-4-95

Case II: Consider Cylindrical Shell hinged at base and free at top with linear external lateral load:

Fig. 5-10

$M_{max} = 0.001 \times 3.1 \times 30^2 = 2.8\ ^{k}/ft$

$M_u = 1.3 \times 1.7 \times 2.8 = 6.2\ ^{k}/ft$

$K_n = 68 \quad \rho_{min} = 0.0033$

$A_s = 0.38\ in^2/ft$

#6@12 Vert. IF.

$V_{max} = 0.04 \times 3.1 \times 30 = 3.72\ ^{k}/ft$

$V_u = 1.7 \times 3.72 = 6.3^k < \phi V_c = 12.3^k/ft$

Consider "Sinking Caisson" method:

Hung-up forces:

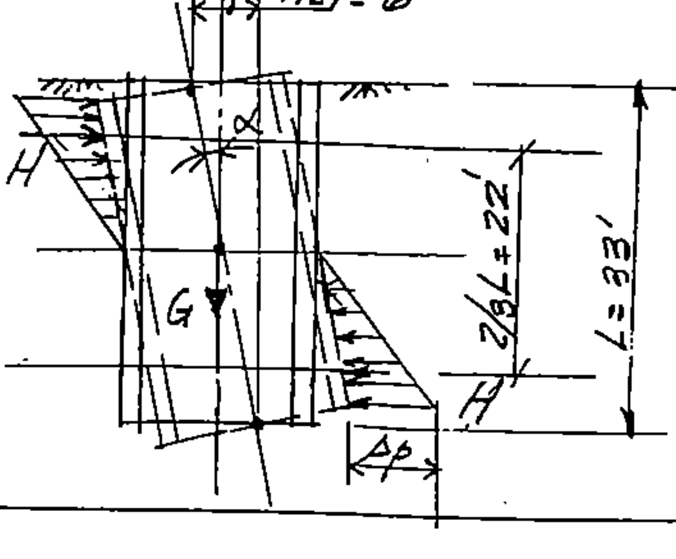
$T = 0.33 \times 1.0 \times 33' \times 0.150 = 1.69\ ^{k}/ft$

$T_u = 1.67 \times 1.4 \times 1.69 = 3.97\ ^{k}/ft$

$A_{s_t} = \frac{3.97}{0.9 \times 60} = 0.074\ in^2/ft$

Tilting Stresses:

Ref: "Art of Tunnelling" K. Szechy, pg. 793-794.



G = wt. of Sinking Caisson

$= \pi \times 9 \times 33 \times 1.04 \times 0.150 = 146^k$

Consider maximum tilt of 6 inches.

$\eta = \tan\alpha = \frac{6}{12 \times 33} = 0.01515$

$H = \eta G = 2.21^k$

$M = H \times 2/3 L = 48.7^{k}$

$S_{xx} = \frac{\pi(10^4 - 8^4)}{64 \times 5} = 57.96\ ft^3$

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON		JOB NO. 3904.00 0101
	SUBJECT: Lift Stn - 2 Pumps w/ 100.-300 GPM each		SHEET 4
	DESIGNED: NMP	DATE: 12-8-94	CHECKED: [signature] DATE: 1-4-95

$f_b = \frac{48.7}{57.96} = 0.84\,ksf = 6\,psi$ axial Compression or Tension in walls.
$= 0.84\,k/ft$

$T_{max} = 1.69 + 0.84 = 2.53\,k/ft$

$T_{u\,max} = 1.65(1.69 \times 1.4 + 0.84 \times 1.7) = 6.33\,k/ft$

$\Delta A_{st} = 6.33/60 \times 0.9 = 0.12\ in^2.$
$= 0.06\ in^2/ft$ ea face.

$\Sigma A_s = 0.38 + 0.06 = 0.44\,in^2/ft$ — #6@12" V EF.
$= 0.78 + 0.06 = 0.84\,in^2/ft$ — #6@6" V EF. at bottom 3rd of Caisson.

$H = 2.21^k = \Delta p\,h/4$

$\Delta p = \frac{2.21 \times 4}{33} = 0.268\,ksf$ or 268 psf

$P_{at\,base} = 3250 + 268 = 3518\,psf$ (8.2% higher)

$P_{Top} = 100 + 268 = 368\,psf$

Bending due to $\Delta p = 268\,psf$.
Ref: "Stress Coeff. for large horizontal pipes," James M. Paris, ENR Nov. 1921.
Case VIII:

$M_A = 0.337 \times 0.268 \times 5^2 = 2.26\,{}^{k}/ft$

$M_u = 1.3 \times 1.7 \times 2.26 = 5.0\,{}^{k}/ft$

Horizontal Reinf. $\rho_{min} = 0.0033$
$A_s = 0.44\,in^2$ — #5@12 Horiz. Ea Face. "ok"

$d = 12.5 - 2.5 - 1 = 11"$
$F = 0.121$
$K_n = 41.$ $\rho_{min} = 0.0013 \times 1.33 = 0.0018$
$A_s = 0.24\,in^2/ft$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF Houston			JOB NO. 3904-00 0101
	SUBJECT: Lift Sta: 2 pumps 100-300 GPM/pump			SHEET 5
	DESIGNED: NMP	DATE: 12-8-94	CHECKED: ABG	DATE: 1-4-95

Resistance to Buoyancy:

Consider total depth = 33'0"

Top slab 24" = $\pi \times \frac{10.08^2}{4} \times 2.0 \times 0.150 = 23.94^k$

Base slab 24" $= 23.94$

walls: $\pi \times 9.04 \times 1.04 \times 29 \times 0.150 = 128.48$

(28') ok, say $W_{DL} = 176.36^k$

Uplift force; consider flood up to T/Top slab

$P = \frac{\pi \times 10.08^2}{4} \times 33 \times \frac{62.4}{1000} = 164.32^k \uparrow$

Factor of Safety against floatation $= \frac{176.36}{164.32} = 1.07$ < 1.40 min reqd.

$\Delta W = 1.40 \times 164.32 - 176.36 = 53.69^k$

c or $\tau_f = \frac{53690}{\pi \times 10.08 \times 33} = 51$ psf

NOTE:

Design Consultant to Verify with geotechnical Consultant value of adhesion and/or friction between Caisson wall and Soils. Pressure grouting can restore 50 psf and larger adhesion/friction.

Base Slab:

Uplift pressure $= 62.4 \times 33' = 2.06$ ksf.

Total uplift $= 2.06 \times \frac{\pi \times 8^2}{4} = 103.5^k$

peripherial shear $= 4.12^k/ft$

OK ALSO BY INDEPENDENT CHK.

$M_r = M_T = \frac{103.5}{16\pi}(3 + 0.2) = 6.6^{1k}$ Orthogonal Steel.

$M_u = 1.67 \times 1.7 \times 6.6 = 18.7^{1k}/ft \times 1.41 = 26.4^{1k}$

$d = 18 - 3 - 1 = 14"$ $F = 0.196$ $K_n = 135$, $\rho_{min} = 0.0033$ $A_s = 0.55 in^2/ft$

#5@12 B. H. EW and #7@12 T. EW.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT City of Houston		JOB NO. 3904-00 0101
	SUBJECT Lift Station: 2 Pumps 100-300 GPM/pump		SHEET 6
	DESIGNED NMP	DATE 12-12-94	CHECKED A Ah	DATE 1-3-95

Top slab:

Design loads : LL $= 300\,psf$
or H-20 Truck loading.
DL: 24" conc. slab = 300 psf
(w/o Beams)

$f'_c = 4000\,psi$, $f_y = 60{,}000\,psi$.

Wetwell = 8'-0 diameter

$l = 8'$ max.

$M_{DL} = 0.3 \times 8^2/8 = 2.4^{k}$ — AASHTO LOAD Factor: 3.22.1A

$M_{LL} = 0.3 \times 8^2/8 = 2.4^{k} \times \overbrace{1.3 \times 1.0} = 3.1$

or $= 0.9 \times 8 \times 1.3 = 9.4^{1k} \times 1.3 \times 1.67 = \underline{20.3\ ^{1k}/ft}$

$(d = 18'' - 2 - \tfrac{1}{2} = 15.5'')$ $\quad M_{u_{des}} = \underline{\underline{23.4\ ^{1k}/ft}}$

$d = 24 - 2 - \tfrac{1}{2} = 21.5''$

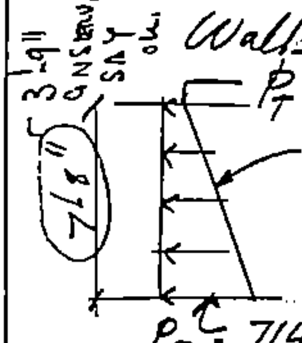
$F = 0.462\ (0.24)$ $\quad M_u = 1.3 \times 23.4 = 30.4\ ^{1k}/ft$, $K_n = 66.\ (127.)$, $\rho_{min} = 0.0033$

$A_s = 0.85\,in^2/ft$ #7@8" Bott. (parallel to Long side
(0.62 in²/ft (#6@8 Bott) of Access opng).
#5@8 T & Bott. (Transverse)

NOTES • Provide addl. bars each side of opngs to compensate for interrupted by opngs.
• Provide similar reinf. for Valve Vault Top Slab.

Valve Vault: Consider flood condition w/ Saturated soil

Walls:



$P_T/P_B = 0.14$

$t = 12''$

$d = 9.5''$

$F = 0.090$

#5@8" VEF
#4@12 HEF.

$Q = \dfrac{100 + 714}{2} \times 7.67' = 3.12^{k}$

$M_{max} = \dfrac{3.12 \times 7.67}{7.82} = 3.1\ ^{1k}/ft$

$V_T = 0.35 \times 3.12 = 1.12\ ^{k}/ft$

$V_B = 2.0\ ^{k}/ft$

$M_u = 1.7 \times 1.3 \times 3.1 = 6.9\ ^{1k}/ft$

$K_n = .77$ $\quad \rho_{min} = 0.0033$

$A_s = 0.38\,in^2/ft$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0101
SUBJECT: LIFT STATION - 2 PUMPS 100-300GPM/Pump			SHEET 7
DESIGNED: NMP	DATE: 12-12-94	CHECKED: AAG	DATE: 1-3-95

Valve Vault Base Slab:

Loads: Topslab DL $= 300 psf$
LL $= 300 psf$
or $2 \times \underbrace{1.3}_{\text{IMPACT}} \times 16^k / 8.33 \times 7.83 = 638$ psf ✓

CONSERVATIVE - [3'-9" - 2½" = 1.75']

Walls: $\dfrac{6.67(5.83 + 2 \times 8.33) \times 1.0 \times 0.15}{8.33 \times 7.83} = 345$ psf
(22.5 k)

$\therefore W_u = (1.4 \times 645 + 1.7 \times 638) = 1.99$ ksf
(No sanitary factor = 1.3 used).

$M_u = 1.99 \times 6.83^2/8 = 11.6$ 'k/ft $K_n = 59$

or $A/B = 6.83/8.33 = 0.82$

REF. ACI 318-63 METHOD 3 TABLE 2 CASE 1

$M_A = 0.056 \times 1.99 \times 6.83^2 = 5.2$ 'k/ft $K_n = 27$
$M_B = 0.023 \times 1.99 \times 8.33^2 = 3.2$ 'k/ft
$d = 18 - 3 - 1 = 14"$ $F = 0.196$ $\rho_{min} = 0.0033$
$A_s = 0.55$ in²/ft
#6@8" Top EW.
#5@12 Bott EW.

Consider Base slab as Cantilever from wetwell
$\ell = 7.33'$

$M_u = 1.99 \times 7.33^2/2 = 53.5$ 'k/ft
$K_n = 272$ $\rho = .0053$ $A_s = 0.89$ in² #6@6" Top
SAY CONSERV. - MOM. TRANSFER TO WALL ∴ "OK" or #7@8" Top ✓
#8@12 Top
Dwls from Wall

Valve Vault Buoyancy check; CONSERVATIVE
Uplift: $7.83 \times 8.33 \times 10.17 \times 62.4 / 1000 = 41.4^k \uparrow$ or

DL: Topslab $(7.83 \times 8.33 - 5 \times 5) \times 2 \times 0.150 = 12.0^k$
Base slab $7.83 \times 8.33 \times 1.5 \times 0.150 = 14.7$
Walls: $(5.83 + 2 \times 8.33) 6.67 \times 1 \times 0.150 = 22.5$
$49.2^k \downarrow$

F.S. against Floatation $= \dfrac{49.2}{41.4} = 1.20$

Note: Ftg extension and Soil on Ftg will increase F.S.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0101
	SUBJECT: LIFT STATION - 2 PUMPS 100 - 300 GPM / PUMP			SHEET 8
	DESIGNED: NMP	DATE: 12-14-94	CHECKED: DAB	DATE: 1-4-95

Valve Support Pad: (No Vault):

Consider ave. length of Cantilever = 8.33'.

Loads: 12" Conc. Slab = 150 psf

LL = 300 psf

or H-20 Truck loading: (during construction only

$M = 0.150 \times 8.33^2/2 = 5.20^{k}/ft \quad \times 1.4 = 7.3^{k}$

$= 0.300 \times 8.33^2/2 = 10.4\ k/ft \quad \times 1.7 = 17.7^{k}$ } 25^{k}

or $2 \times 1.30 \times 16 \times \frac{7.33}{7.25} = 42.\ ^{k}/ft \quad \times 1.7 = 71.4$

$d = 12'' - 2 - \frac{1}{2} = 9.5''$

$F = 0.09$

$A_{s\,min} = 0.37\ in^2$

#5 @ 8" (TYP).

No truck Allowed.

$M_u = 25.0\ ^{k}/ft$

$K_n = 278 \quad \rho = .0054$

$A_s = 0.61\ in^2$

#5 @ 6 Top Dwls from Wetwell Top slab.

Thrust blocks:

Assume 8" ϕ pipe w/ 50 psi pressure

$T = \frac{\pi \times 8^2}{4} \times 50 = 2512^{lb} \approx 3^{k}$

$M = 3.00 \times 3.50'$ above floor $= 10.5^{k}$

$M_u = 1.7 \times 10.5 = 17.9^{k}$

$V_u = 1.7 \times 3 = 5.1^{k} < \phi V_c = 0.85 \times 2 \sqrt{4000} \times 12 \times 9.5 = 12.3^{k}$

$bt = 12 \times 12'' \quad d = 9.5'' \quad F = 0.09$

$K_n = 199 \quad \rho = .0039$

$A_s = 0.44\ in^2 \quad$ 2 #5

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON		JOB NO: 3904-00 0101
	SUBJECT: LIFT STN - 2 PUMPS 100-300 GPM/PUMP		SHEET 9
	DESIGNED: NMP	DATE: 12-19-94	CHECKED: A. Alr — DATE: 1-4-95

Assume 20" ϕ Pipe w/ 50psi pressure @ 42" above floor

$T = \frac{\pi \times 20^2}{4} \times \frac{50}{1000} = 15.7^k$ $\quad V_u = 1.7 \times 15.7 = 26.7^k$

$M_u = 15.7 \times 3.5 \times 1.7 = 93.4^{1k}$ $\quad \phi V_c = 0.85 \times 2\sqrt{4000} \times 20'' \times 17.5'' = 37.6^k$

$bt = 20'' \times 20''$ $\quad d = 20'' - 2'' - \frac{1}{2}'' = 17.5''$ $\quad F = 0.508$

$K_n = 184$ $\quad \rho = 0.0035$

$A_s = 1.22 in^2$ 3#6 or 4#5

12" ϕ pipe w/ 50psi pressure @ 42" off the floor

$T = 6^k$

$M_u = 6 \times 3.5 \times 1.7 = 35.7^{1k}$

$V_u = 6 \times 1.7 = 10.2^k < \phi V_c = 12.3^k$

$bt = 12'' \times 12''$ $\quad d = 9\frac{1}{2}''$ $\quad F = 0.09$

$K_n = 397$ $\quad \rho = 0.0079$

$A_s = 0.90 in^2$ 3#5

Base Slab:
8" ϕ $\quad M_u = 17.9^{1k}$ $\quad \frac{M_u}{3.58'} = 5.0^{1k/ft}$
12" ϕ $\quad M_u = 35.7'$ $\quad = 10.0$
20" ϕ $\quad M_u = 93.4'$ $\quad = 26.0^{1k/ft}$

$d = 10'' - 2 - \frac{1}{2} = 7.5''$, $F = 0.056$

	K_n	ρ	A_s	Provide
8" ϕ	89.	0.002	0.18 in²	< #5@8 T(min)(0.46)
12" ϕ	179.	0.0035	0.32	< #5@8 T(0.46)
20" ϕ	464	0.0093	0.84	< #5@8" T Add'l (0.92)

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, Tx Stls ZP-55C Pump STN.-C2		JOB NO. 3921-00 0101
	SUBJECT 2 Pumps @ 250-500 GPM Low Profile-secured		SHEET 1 of 3
	DESIGNED NMP	DATE 11-29-95	CHECKED	DATE

VALVE VAULT: 12'X12'-2"X8'-8" Walls t=12"

Grating - FRP = 25 PSF
LIVE LOAD = 150 PSF
W = 175 psf.

GRATING SUPP. BEAM;

$L = 10'\text{-}2''$

$w = 175\left(\frac{3.17+2.92}{2}\right) = 533\ plf$

Bm. wt. = 42

575 plf

$M = 0.575 \times 10.17^2/8 = 7.4^{\prime k}$

$V = 0.575 \times 10.17/2 = 2.92^k$ W8X15 $l_u = 10.17'$

$M_R = 15.^{\prime k}$

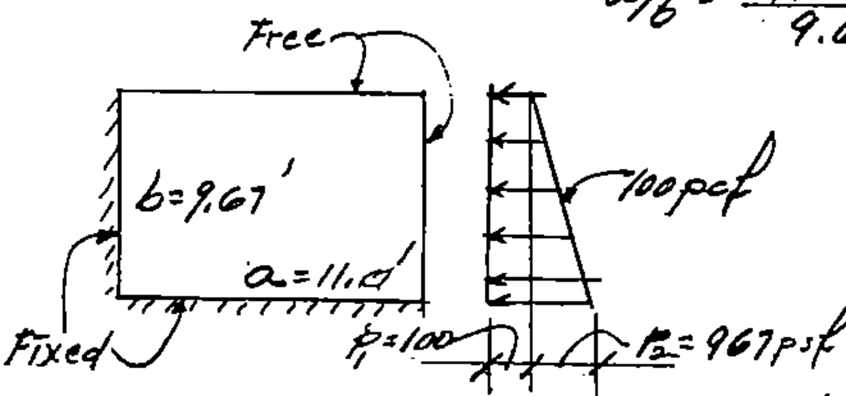
Provide Single plate shear connection
3/8" PL X 6"X6" W/ 2-13/16"X1½" Horiz Slotted holes for 2-3/4" DIA A325 Bolts.

$V_{allow} = 8.2^k > V = 2.92^k$

Wall Face PL 3/8"X6"X8" W/ 2-3/4"φX6"Lg Studs.

PIT WALLS:

$a/b = \frac{11.0'}{9.67} = 1.14 \approx 1.00$



$p_1 \bar{b} = 1.1$
$p_1 b^2 = 9.4$
$p_2 \bar{b} = 9.4$
$p_2 \bar{b}^2 = 90.4$

$M_x^- = 0.2949 \times 9.4 + 0.0662 \times 90.4 = 8.8^{\prime k}$ $M_{u_x}^- = 14.9^{\prime k}/ft$

$M_x^+ = 0.0324 \times 9.4 + 0.0077 \times 90.4 = 1.0^{\prime k}$ $= 1.7^{\prime k}/ft$

$M_y^- = 0.2949 \times 9.4 + 0.1157 \times 90.4 = 13.2^{\prime k}$ $= 22.5^{\prime k}/ft$

$M_y^+ = 0.0324 \times 9.4 + 0.0172 \times 90.4 = 1.9^{\prime k}$ $= 3.2^{\prime k}/ft$

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, Tx Stds.		JOB NO 3921-00 0101
	SUBJECT 2 Pumps @ 250-500 GPM EA. Secured Site		SHEET 2 OF 3
	DESIGNED WMP	DATE 11-30-95	CHECKED	DATE

$t = 12''$ $d_V = 12''-2-\frac{1}{2} = 9.5''$ $F = 0.093$

$d_H = 12-3-\frac{1}{2} = 8.5''$ $F = 0.072$

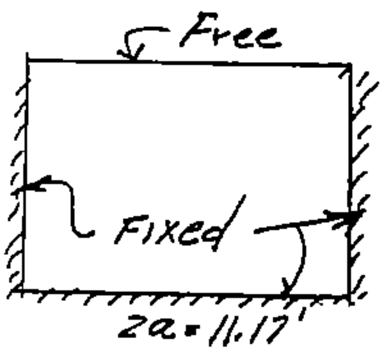
$K_{nH}^- = 207$ $\rho = 0.0040$ $A_{sH}^- = 0.54\ in^2/ft$ #5@12" OF @ Corners

$K_{nH}^+ = 24$ $\rho = 0.0013$ $A_{sH}^+ = 0.18\ in^2/ft$ #4@12 HEF.

$K_{nV}^- = 242$ $\rho = 0.0047$ $A_{sV}^- = 0.71\ in^2/ft$ #5@6 Dwls OF

#5@12 " IF.

$K_{nV}^+ = 34$ $\rho_{min} = 0.0013$ $A_{sV}^+ = 0.20\ in^2/ft$ #4@12 V EF.



$a/b = \frac{11.17}{2 \times 9.67} = 0.58$

$M_x^- = 0.8592 \times 9.4 + 0.0406 \times 90.4 = 11.7^{k/ft}$ $M_u = 20^{k/ft}$

$M_x^+ = 0.0807 \times 9.4 + 0.0214 \times 90.4 = 2.7$ $= 4.6$

$M_y^- = 0.1212 \times 9.4 + 0.0584 \times 90.4 = 6.4$ $= 10.9$

$M_y^+ = 0.0245 \times 9.4 + 0.0139 \times 90.4 = 1.5$ $= 2.5^{k/ft}$

$K_{nH}^- = 278$ $\rho = 0.0054$ $A_{sH}^- = 0.73\ in^2$ #5@8" OF @ Corner

$K_{nH}^+ = 63$, $\rho = 0.0013$ $A_{sH}^+ = 0.18$ #4@12 HEF

$K_{nV}^- = 117.$ $\rho = 0.0023$ $A_{sV}^- = 0.35$ #5@6" DWL OF

#5@12 DWL. IF

$K_{nV}^+ = 27.$ $\rho = 0.0013$ $= 0.20$ #4@12 VEF

BASE SLAB

Dead Loads: 12" walls $2 \times 11.5 \times 8.67 \times 0.150 = 29.9^k$

$1 \times 10.17 \times 8.67 \times 0.150 = 13.2$

16" Base Slab $= 11.5 \times 12.17 \times 1.33 \times 0.150 = 27.9$

Soil wt: $(2 \times 12.5 + 12.17) \times 10.00 \times 0.06 = \underline{22.3}$

$93.3^k \downarrow$

Uplift $= 11.5' \times 12.17' \times 10.0 \times 0.062 = 87.3^k \uparrow$

Factor of Safety against floatation $= \frac{93.3}{87.3} = \underline{1.07 < 1.25}$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, Tx Stds			JOB NO. 3921-00 0101
	SUBJECT 2 Pumps - 250 - 500 GPM Secured Site Pump St.			SHEET 3 of 3
	DESIGNED NMP	DATE 11-30-95	CHECKED	DATE

Resisting force required $= 1.25 \times 87.3 - 93.3$
$= 15.8^k$

Shear Transfer to Wet well will provide; $\frac{15.8}{2} = 7.9^k/_{wall}$

NOTE: See Sht. 2 of 4 of 3-pumps, 250-2000 GPM EA. Secured Site pump Stn. Calcs. For wall bracket and dowel bar designs.

BASE SLAB:

$\ell = 11.17'$

net uplift $= 0.062 \times 10' = 0.624$ ksf $\times 1.7 = 1.061$

16" Slab $= 0.200$ " $\times 1.4 = 0.280$

0.424 psf ↑ $\qquad 0.781$

$M_u = 0.781 \times 11.17^2/8 \times 1.3 = 15.8^{lk}/ft$

$V_{u_d} = 0.781 \times \left(\frac{11.17}{2} - 1.5\right) = 3.19^k/ft < 2 \times 0.85\sqrt{4000} \times 12 \times 12.5 = 16.1^k = \phi V_c$

$t = 16''$ $\quad d = 16 - 3 - \frac{1}{2} = 12.5''$ $\quad F = 0.156$

$K_n = 101$ $\quad \rho = 0.002$ $\quad A_s = 0.40 in^2/ft$

#5 @ 8" T EW and
#5 @ 12" Bot EW.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904.00-0101
	SUBJECT: STD. PUMP STN - 2 PUMP. 250 - 500 GPM EA.			SHEET 1
	DESIGNED: NMP	DATE: 10-25-94	CHECKED: JAM	DATE: 11.4.94

(Sht. C2)

DESIGN CRITERIA:

Design Grade Floor:

Live Load:

H-20 Truck Loading. OR

Max. Pump Wt. = 5000 lbs. or 2/DL = 300 psf.

Dead Load:

Consider 24" slab w/o Beams - Simple and Cost-effective.

24" Conc. = 300 psf

$f'_c = 4000$ psi, $f_y = 60{,}000$ psi

WET WELL:

$l = 2 \times \sqrt{5.50^2 - 1.38^2} = 10.65$ ft

$L_c = 12.65$ ft c/c

$w_{DL} = 300$ psf, $M_{DL} = 0.3 \times 12.65^2/8 = 6.0$ k/ft $\quad M_{DLu} = 1.3 \times 1. \times 6.0 = 7.8$ k/ft

$w_{LL} = 300$ psf $\quad M_{LL} = 6.0$ k/ft

H-20 Truck (AASHTO, 3.22.1A Table factors)

Impact.

$M_{LL_1} = 0.9 \times 12.65 \times 1.3 = 14.8$ k/ft $\quad M_{LLu_1} = 1.3 \times 1.67 \times 14.8 = 32.1$ k/ft controls

$M_{LL_2} = \frac{(12.65+2)}{32} \times 16 \times 1.3 = 9.5$ k/ft

Sanit. factor

$M_{u_{des}} = (7.8 + 32.1) \times 1.3 = 51.9$ k/ft

$d = 24 - 2 - \frac{1}{2} = 21.5"$ $\quad K_n = 112$

$F = 0.462$ $\quad \rho = 0.0022$

$A_s = 0.85$ in² $\quad \rho_{min} = 0.0033$ ✓.

#6 @ 6" Bottom (0.88 in²/ft).

Use → #7 @ 8" Bott. (Parallel to Long side of Opng).

#5 @ 8" Bott & Top (Transverse direction).

NOTE: Provide Addl bars equal to ℓ Interrupted by opng on ea. side of opng (Stnct. Std.)

VALVE VAULT:

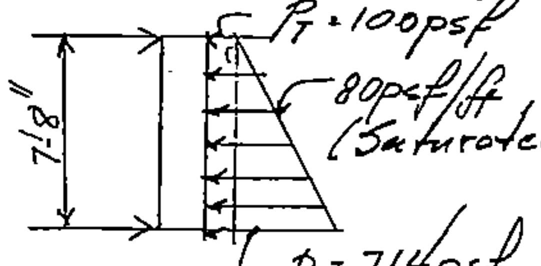
Top Slab:

$l = 11.17'$ Use Same reinf as Wetwell Top Slab.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX			JOB NO: 3904-00.0101
	SUBJECT: STD. PS - 2 Pumps 250 - 500 GPM EA.			SHEET: 2
	DESIGNED: NMP	DATE: 10-25-94	CHECKED: JAM	DATE: 11-4-94

VALVE VAULT WALLS:

Consider Flood Condition with Soil Saturated to full height, equivalent Lat. pressure of 80psf.



$P_T/P_B = 0.14$

$Q = \frac{100+714}{2} \times 7.67' = 3.12^k$

$M_{max} = \frac{3.12 \times 7.67}{7.82} = 3.1\ ^{k}/ft$

$V_T = 0.35 \times 3.12 = 1.12^k$

$V_B = 0.65 \times 3.12 = 2.0^k$

Wall Vert span = 6'-8"
wall thick. = 1'-0"
7'-8"

sanit. Factor

$M_u = 1.7 \times 1.30 \times 3.1 = 6.9\ ^{k}/ft$

$d = 12" - 2" - \frac{1}{2}" = 9.5"$, $F = 0.090$

$K_n = 76$ $\rho = 0.0014$

$\rho_{min} = 0.0033 \leftarrow$ Use

$A_s = 0.38 in^2/ft$

#5@8" Vert EF.

#4@12" Hor. EF.

VALVE VAULT BASE SLAB:

$A = 11'-2"$
$B = 12'-10\frac{1}{2}"(\pm)$. $m \cong 0.87$.

Loads: Top Slab = 300psf.

35.92k

Walls $\frac{(10.17' + 2 \times 12.87') \times 0.150 \times 6.67'}{13.17' \times 13.87'} = 197$ "

LL ; $2 \times 20.8 / 13.17 \times 13.87 = 227 psf$.

or = 300psf.

797 psf.

$M = 0.797 \times 11.17^2/8 = 12.4\ ^{k}/ft$, $M_u = 24.2\ ^{k}/ft$

or $M_A = 0.050 \times 0.797 \times 11.17^2 = 5.0\ ^{k}/ft$ $M_u = 1.3 \times 1.5 \times 5.7 = 9.8\ ^{k}/ft$

$M_B = 0.026 \times 0.797 \times 12.87^2 = 3.4\ ^{k}/ft$ $K_u = 68$ $\rho = 0.0013$

$d = 16 - 3 - 1 = 12"$ $F = 0.144$ Use $\rightarrow$ $\rho_{min} = 0.0033$, $A_s = 0.48$

#5@8 TOP EW
#5@12 BOTT EW } t = 16"

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX.		JOB NO. 3909.00-0101
	SUBJECT: STD. PS. - 2 PUMPS 250-500 GPM. WITHOUT VAULT.		SHEET 3
	DESIGNED: NMP	DATE: 10-26-94	CHECKED: JAM — DATE: 11-4-94

VALVE PAD: (Sht. C4)

Consider average length of Cantilever = 8'-8".

Loads: 10" Conc. slab = 125 psf × 1.4 = 175
LL (No Truck possible) = 150 psf × 1.7 = 255
275 psf. = 430 psf

$M = 0.28 \times 8.67^2/2 = 10.5^{k'}/ft \times 1.56 = 16.4^{k'}/ft = M_u$

$V = 0.28 \times 8.67' = 2.43^k/ft = 3.8^k/ft = V_u$

$d_T = 10" - 2" - 1" = 7.0"$ $F = 0.049$

$d_B = 10 - 3 - \frac{1}{2} = 6.50"$ $K_n = 335$ $\rho = 0.0067$

$F = 0.0423$ $A_s = 0.56 in^2/ft$ #5@8" Top Cont.
#5@12 Top Add'l. ($A_s = 0.78 in^2/ft$)
OR #5@6" dwls.

NOTE: All other details same as before.

Alt: $A = 7'-8"$, $B = 8'-2"$, $m = 0.94$ ACI-method-3 (68).

$M_A = 0.040 \times .275 \times 7.67^2 = 0.65^{k'}/ft$

$M_B = 0.033 \times .275 \times 8.17^2 = 0.61^{k'}/ft$

Provide #5@12 T&B EW (min).

$V_A = 0.55/2 \times 0.275 \times 7.67' = 0.58^k/ft$

$V_B = 0.45/2 \times 0.275 \times 8.17 = 0.51^k/ft$

Provide 1'-0" width at bottom of Gr. Wall -

check Bouyancy of Vault:

h_w = 2.0' Top slab
6.67 Walls
1.50 Base slab
h_w = 10.17

uplift = 62.4 × 10.17 = 635 psf ↑

ΣDL = 24" Top slab = 300 psf
12" walls = 197 "
18" Base = 225 "
Soil = 60 "
782 psf ↓

$F.S = \frac{782}{635} = 1.23$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, Tx Stds LP-SSC Pump STN. D2	JOB NO. 3921.00 0101
	SUBJECT 3 Pumps @ 250-2000 GPM Low Profile - Secured	SHEET 1 of 4
	DESIGNED NMP / DATE 11-10-95 / CHECKED	DATE

Valve Vault: 15'-0" × 20'-3" × 8'-8" Walls t = 12"

Grating: FRP = 25 psf
LL = 150 "
175 psf

Beam: $L = 18'\text{-}3''$

$w = 175\,psf \times \left(\dfrac{4.33+3.17}{2}\right) = 656\,plf$

Bm Wt say = 44
700 plf.

$M = \dfrac{0.7 \times 18.25^2}{8} = 29.1^{k'}$

$W = 12.78^k \quad V = 6.39^k$ W8X24 $M_R = 31^{k'}$, $l_u = 18.25'$

$\Delta_{approx} = \dfrac{1.00 \times 12.78}{18} = 0.71'' = \dfrac{L}{308}$ ✓

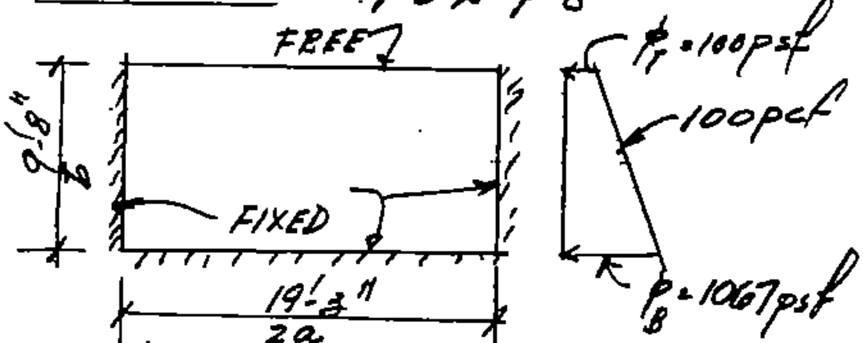
Single-plate Shear Connection, Table X-A pg 4-34
3/8" PL × 6" × 6 w/ 13/16 × 1½" Long (Horiz) Slotted
Holes for 2 - ¾" φ A325 Bolts.

$V_{allow} = 8.2^k > V = 6.39^k$

Wall face PL = 3/8" × 6 × 8" w/ 2 - ¾" φ × 6" Long Studs.

Pit Walls: Ref: BOR, EM. No. 27

End Panel: 19'-3" × 9'-8"



$a/b = \dfrac{19.25}{2 \times 9.67} \doteq 1.00$

$p_T b^2 = 9.35$

$p_T b = 0.97$

$p_B' b^2 = 0.967 \times 9.67^2 = 90.4$

$p_B' b = 0.967 \times 9.67 = 9.35$

$M_x^+ = 0.1 \times 9.35 + 0.0276 \times 90.4 = 3.43^{k/ft}$ $M_u = 5.8^{k/ft}$

$M_x^- = 0.2613 \times 9.35 + 0.0644 \times 90.4 = 8.26$ $= 14.0$

$M_y^- = 0.2043 \times 9.35 + 0.0845 \times 90.4 = 9.55^{k/ft}$ $= 16.2^{k/ft}$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston Tx ~ Stds.		JOB NO. 3921-00 010/
	SUBJECT: 3 Pump Sta - Valve Vault		SHEET 2 of 4
	DESIGNED: NMP	DATE: 11-13-95	CHECKED	DATE

$M_y^+ = 0.0243 \times 9.35 + 0.0159 \times 90.4 = 1.7^{\#}$ $M_u = 2.9^k$

$d_V = 12 - 2 - \frac{1}{2} = 9.5''$ $F_V = 0.09$
$d_H = 12 - 3'' - \frac{1}{2} = 8.5''$ $F_H = 0.07$

$K_H^- = 200.$ $\rho_H^- = 0.0039$ $A_{sH}^- = 0.40 in^2/ft$ #5@12 HOF
#5@12 HOF@ Col.
$K_H^+ = 83.$ $\rho_H^+ = 0.0016$ $A_{s\,min} = 0.33 in^2/ft$ #5@12 HIF.
$K_V^- = 180.$ $\rho_V^- = 0.0034$ $A_{sV}^- = 0.39$ #5@12 VOF
#5@6" VOF DWLS
$K_V^+ = 32.$ $\rho_V^+ = 0.0013$ $A_{sV\,min}^+ = 0.37$ #5@12 VIF

Base Slab:

Loads: DL: 1' walls $2 \times 8.67' \times 14.50' \times 0.150 = 37.7^k \downarrow$
16" Base slab $= 20.25 \times 15' \times 1.33 \times 0.150 = 60.6^k \downarrow$
1' wall $1 \times 19.25' \times 8.67 \times 0.150 = 25.0$
$123.3^k \downarrow$

Uplift $= 15' \times 20.25 \times 9' \times 0.062 = 170.6^k \uparrow$

Try 16" wide projection of Base slab.
Soil wt $= 0.06 \times 1' \times 9'(18.25 + 2 \times 15.50') = 40.9^k \downarrow$

ΔW_{DL} reqd $= (1.25 \times 170.6 - 123.3 - 40.9) = 49.^k \downarrow$

Consider this provided by Shear transfer thru Side Wall to Wet well:

$V = 24.5^k$/wall. #7@12" dwls = 8 #7 dwls.

$A_b = 0.60 in^2$

$\phi V_c = 0.85 \times 800 \times 0.6 \sqrt{4000} = 25804^{\#}$

OR $= 0.85 \times 2\pi \times 6^2 \sqrt{4000} = 12160^{\#}$

$V_u = 24.5 \times 1.7 = 41.65^k < 8\#7 = 12.16 \times 8 = 97.28^k$

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 12 \times 96 = 123.86^k \gg V_u = 41.65^k.$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	Houston Tx Stds PROJECT			3921-00 JOB NO. 0101
	3 Pumps - 250 - 2000 GPM SUBJECT			3 of 4 SHEET
	NMP DESIGNED	11-13-95 DATE	CHECKED	DATE

Bracket from wet Well wall:

Consider 5' wide base slab and 5'-0" of walls from Vault supported on to bracket.

P_{slab} = 1'-6" slab @ 225 psf x 5' = 1125 #/ft
LL @ 150 psf x 5' = 750
P = 1875 #/ft

P_{wall} = 0.150 X 8.67' X 5' = 6.50 k
w = 2'-6" slab = 375 psf.

Assume Wet Well wall t = 2'
l_{min} = 1'-0"
l_{max} = (10.25' - 10.25 Cos 45°) + 1.00' = 4.00'
l_{ave} = 2.5'

M_{ave} = 0.375 X 2.5²/2 = 2.3 k/ft
1.875 X 2.5 = 4.7
7.0 k/ft

M_{max} = 0.375 X 4²/2 = 3.0
1.88 X 4' = 7.52
10.52 k/ft X 1.7 = 17.9 k/ft

d = 18 - 2 - 1 = 15"
F = 0.225 K_m = 80 ρ_{min} = 0.002
A_s = 0.32 in²/ft
Provide #6 @ 12 (0.44).

Wall as bracket: L = 4.60'
P = 6.5 k. w = 1.3 k/ft
OR P_{uplift} = 24.5 k

M_{DL} = 6.5 X 4.6' = 30.0 k
1.3 X 4.6²/2 = 14.0
44.0 k

M_{uplift} = 24.5 X 4.6 = 113 k

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, Tx Stds.			JOB NO. 3921-00 1010
	SUBJECT: 3 Pumps - 250-2000 GPM			SHEET 4 OF 4
	DESIGNED: NMP	DATE: 11-14-95	CHECKED	DATE

Ref: PCA - "Simplified Design" shear walls, pg. 6-13

$M_{u_1} = 1.4 \times 44 = 62^k$

$M_{u_2} = 1.7 \times 113 = 192^k$ ← controls.

$P_u = 0$

$\phi M_n = \phi\left[0.5 A_{st} f_y l_w \left(1 + \frac{P_u}{A_{st} f_y}\right)\left(1 - \frac{c}{l_w}\right)\right]$

$A_{st} = $ #6@12 HEF $= 0.44 \times 8 \times 2 = 7.04\ in^2$

$\frac{c}{l_w} = \frac{\omega}{2\omega + 0.85\beta_1}$ $\beta_1 = 0.85$ for $f'_c = 4000$

$= \frac{0.085}{0.17 + 0.72} = 0.095$

$l_w = 8.67 \times 12 = 104''$

$\omega = \frac{A_{st}}{l_w h} \times \frac{f_y}{f'_c} = \frac{7.04}{104 \times 12} \times \frac{60}{4} = 0.085$

$\phi M_n = 0.90 \frac{[0.5 \times 7.04 \times 60 \times 104 \times 0.905]}{12} = 1490^k \gg 192^k$

Base Slab:

$l = 19'3''$

$W_{uplift} = 9' \times 0.062 - 1.33 \times 0.15 = 0.362$ ksf ↑

$M = 0.362 \times 19.25^2/8 = 16.8^k/ft \times 1.7 \times 1.3 = 37.^k = M_u$

$V = 0.362 \times 19.25/2 = 3.48^k/ft$ $= 7.7^k/ft = V_u$

$t = 16''$ (min) . $d = 16 - 2 - \frac{1}{2} = 13.5''$

$F = 0.182$

$K_n = 203$ $\rho = 0.004$

$A_s = 0.65\ in^2/ft$

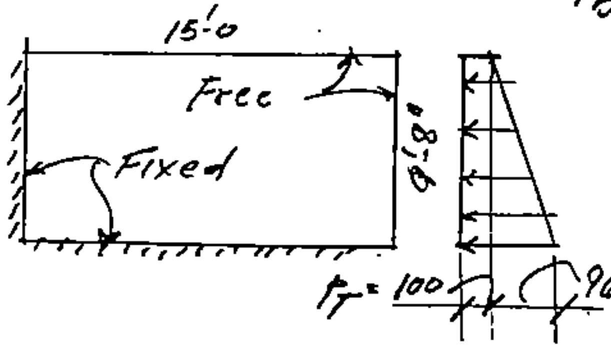
#6@8" T in long direc.

#5@8" T in short

#5@12 BOT EW

Pit Side walls:

$a/b = 15/9.67 = 1.6 > 1.0$ use 1.0



$p_T b^2 = 9.35$ $p_T b = 0.97$

$p_B b^2 = 90.4$ $p_B b = 9.37$

$M_{cant} = 0.1 \times 8.67^2/2 = 3.8^k/ft$

$0.1 \times 8.67^3/6 = 10.9$

M_c $14.7^k/ft$

$p_T = 100$ 967 psf $= p'_B$ $M_u = 25^k/ft$

$K_n = 278$ $\rho = 0.0054$

$A_s = 0.62\ in^2/ft$

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904-00 0101
	SUBJECT: STD-PS-3PUMPS, 250-2000 GPM EA.			SHEET 4
	DESIGNED: NMP	DATE: 10-27-94	CHECKED: JAM	DATE: 11-4-94

WET WELL: (Sht. C6)

TOP SLAB:

LL: Equipment etc. = 300 psf.
OR H-20 Truck loading.
Max pump wt = 5000 lbs

DL: 24" thick Conc. Slab = 300 psf.

$l_{max} = 2\sqrt{2.15^2 + 8.25^2} = 15.92 + 2.0' = 17.92'$

$M_{DL} = 0.300 \times 17.92^2/8 = 12.0^{k'}/ft \times 1.0 = 12.0^{k'}/ft$

$M_{LL} = \left(\frac{17.92+2}{32}\right) 1.3 \times 16 = 12.9^{k'}/ft$

controls

or $= 0.9 \times 17.92 \times 1.3 = 21.0^{k'}/ft \times 1.67 = 35.0^{k'}/ft$

$M_{DL+LL} = 33.0^{k'}/ft$

Sanitary factor

$M_u = 47.0^{k'}/ft \times 1.3 = 61.1^{k'}$

$d = 24 - 2 - \frac{1}{2} = 21.5''$
$F = 0.462$

$K_n = 132$

$\rho = 0.0026$, $\rho_{min} = 0.0033$

$A_s = 0.85 in^2/ft$

#6 @ 6 Bott (0.88).

NOTE: Additional moment due to opngs. $\Delta M = 2.15 \times 12 \times 1.3 = 33.5^{k}$

$\Delta K_n = 72$, $K_n = 204$

$\rho = 0.0048$

$A_s = 1.03 in^2/ft$

#8 @ 8" (1.19) Bott.

#5 @ 8" Temp.

VALVE VAULT:

TOP SLAB:

$l = 19'-3''$

$M_{DL} = 0.300 \times 19.25^2/8 = 13.9^{k'}/ft \times 1.0 = 13.9^{k'}/ft$

$M_{LL} = 0.9 \times 19.25 \times 1.3 = 22.5^{k'}/ft \times 1.67 = 37.6^{k'}/ft$

Addl. Mom. due to opng.

$M_u = 51.5^{k'}/ft$

$\Delta M = 2.0 \times 13.9 = 27.8$

$M_{u\,Des} = 1.3(51.5 + 27.8) = 103^{k'}/ft$

$K_n = 223$

$\rho = 0.0043$

$A_s = 1.10 in^2$ #8 @ 8" Bottom - #5 @ 8 Temp. Steel.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: City of Houston, Tx		JOB NO. 3904-00 0101
	SUBJECT: STD. P.S. – 3 pumps 250-2000 GPM		SHEET 5
	DESIGNED: NMP	DATE: 10-31-94	CHECKED: JAM — DATE: 11-4-94

VALVE VAULT WALLS:

Same as for Pump station – 2 pumps.

BASE Slab:

Loads: Top slab 24" thick = 300 psf — 420

LL = 300 psf use — 510

or $2 \times 20.8 / 20.25 \times 15.0 = 137$ psf

Walls $\frac{(2 \times 15.0' + 18.42') \times 6.67 \times 0.15}{20.25 \times 15.0} = 160$ psf. — 224

$w = 760$ psf $\quad w_u = 1154$ psf (1.52).

$A = 13'8"$

$B = 19'3" \quad m: 0.71$

$M_A = 0.068 \times 1.15 \times 13.67^2 = 14.6$ k/ft

$M_B = 0.016 \times 1.15 \times 19.25^2 = 6.8$ k/ft

$t = 16" \quad d = 16-3-1 = 12"$

$F = 0.144$

$K_{m_A} = 101 \quad \rho = 0.002 \quad \rho_{min} = 0.0033$

$A_{s\,min} = 0.48\ in^2$.

#5 @ 8" T EW

#5 @ 12" Bott EW. $\quad t = 16"$ Base Slab.

check Bouyancy of Valve Vault:

h_w = Top slab t = 2'0" $\quad \Sigma DL$: Top slab = 300 psf

wall ht = 6'8" $\quad$ walls = 160 psf

Base t = 1'6" $\quad$ soil (6") = 60 "

10'2" $\quad$ Base Slab = 225

uplift = 635 psf ↑ $\quad$ 745 psf

$F.S = \frac{745}{635} = 1.17 \approx 1.20$

Note: May increase base slab projection from 6" to 12" $\quad F.S = 1.27$.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904.00 0101
	SUBJECT: STD. P.S. - 3 PUMPS, 250-2000 GPM EA W/O VAULT.			SHEET 6
	DESIGNED: NMP	DATE: 10-28-94	CHECKED: JAM	DATE: 11-4-94

VALVE PAD: (Sht. C9)

Consider two-way slab

$A = 10'\text{-}4''$

$B = 15'\text{-}0''$ $\quad m = 0.69$

$w = 125\,psf \quad 175$
$150\,psf \quad 255$
$275\,psf \quad 430\,psf$
(1.56)

$M_A = 0.068 \times 0.43 \times 10.33^2 = 3.1\ ^{k}/_{ft}$

$M_B = 0.016 \times 0.43 \times 15.0^2 = 1.6\ ^{k}/_{ft}$

$d = 10'' - 3'' - \frac{1}{2}'' = 6\frac{1}{2}''$

$K_{m_A} = 73. \quad \rho = 0.0014$

$A_{s\,min} = 0.25 \quad \#5@12''$

$F = 0423$

Provide #5@12 T&Bott. E.W.

$V_A = \frac{0.85}{2} \times 275 \times 10.33 = 1.21\ ^{k}/_{ft}$

$V_B = \frac{0.15}{2} \times 275 \times 15.00 = 0.31\ ^{k}/_{ft}$

Consider Soil/Bearing press = 1500 psf

$w =$ Gr. Floor $= 1.21\ ^{k}/_{ft}$
GR Bm $10'' \times 20'' = 0.22$
$1.43\ ^{k}/_{ft}$

Width of footing $= 1.43/1.50 = 0.95\,ft$

Provide 12 width at bottom.

Alt: Consider cantilever from Wet Well:

$l = 11.33'$

$W_u = 430\,psf$

$M_u = 0.43 \times 11.33^2/2 = 27.6\ ^{k}/_{ft}$

$d = 12''\,slab - 2 - \frac{1}{2} = 9.5''$

$F = 0.09 \quad K_n = 307$

$\rho = 0.006$

$A_s = 0.68\ in^2/ft$ $\quad$ #6@8 T at Wet well wall.

or #5@8" T + #5@16" Addl. Continuous @ Wall.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0101
	SUBJECT: STD P.S. 3 PUMPS - 2000-5300 GPM/PUMP			SHEET 7
	DESIGNED: NMP	DATE: 10-31-94	CHECKED: JAM	DATE: 11-3-94

WET WELL : TOP SLAB: (Sht. C11)

$l = 7'\text{-}3\tfrac{1}{2}''$
$1'\text{-}6''$
$8'\text{-}9\tfrac{1}{2}$

$w = 12''$ slab $= 150$ psf
LL 2/D. $= 300$ psf
OR H-20 loading.

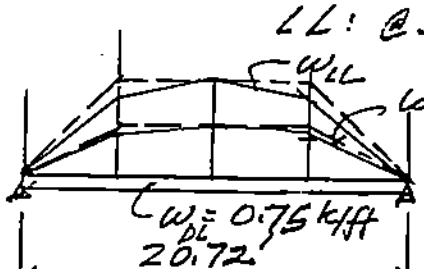
$M = 0.150 \times 8.8^2/8 = 1.45$ k/ft
$0.300 \times 8.8^2/8 = 2.90$ k/ft
or $0.9 \times 8.8 \times 1.3 = 10.3$ k/ft $\times 1.67 \times 1.3 = 22.4^k$

$\times 1.0 \times 1.3 = 1.9^k$ — Sanitary factor

$M_u = 24.30$ k/ft

$d = 12'' - 2'' - \tfrac{1}{2}'' = 9.5$
$F = 0.090$
$K_n = 270$ $\rho = 0.0053$ $A_s = 0.62$ in² #6@8 Bott (Trans)
#5@8 T.EW
#5@8 Bott (Long.)

Beams:
Loads: DL = W_1 at ℄ of span $150 \times 7.3/2 = 0.55$ k/ft
W_2 at ¼ point $150 \times 6.0/2 = 0.45$
Bm wt. $1.5 \times 3.0' \times 0.15 = 0.67$
Hatches @ 30 psf $\times 2.55' = 0.08$ $\} = 0.75$ k/ft
LL: @ 300 psf $\times (3.65' + 2.55' + 1.50') = 2.31$ k/ft $= w_1$
$\times (3.0 + 2.55 + 1.50) = 2.12 = w_2$



Consider $w_{DL} = 0.55$ k/ft in mid-half
$W_{LL} = 2.31$ k/ft in mid-half and 0.0 at support

$W_{DL} =$	7.77^k	7.77^k	
	2.85	2.85	
	1.43	1.43	
$WL =$	11.97 12.05^k	11.97 12.05^k	
	5.98	5.98	
	30.0 17.95^k	30.0^k 17.95	

$M = 30 \times 10.36' = 310.8^k$
$-7.77 \times 5.18 = -40.2$
$-1.43 \times 6.90 = -9.9$ $\} 57.5$
$-2.85 \times 2.59 = -7.4$
$-11.97 \times 2.59 = -30.9$
$-5.98 \times 6.90 = -41.3$ $\} 72.2$
181.1^k

$V_u = 12.05 \times 1.4 = 16.87$
$17.95 \times 1.7 = 30.53$
$V_u = 47.40^k$ (1.58)

$M_u = 491 - 1.4 \times 57.5 - 1.7 \times 72.2$
$= 491 - 80.5 - 122.7 = 287.8^k$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON			JOB NO. 3904.00 0101
SUBJECT: STD PUMP STN. 3 PUMPS 2000-5300 GPM ea			SHEET 8'
DESIGNED: NMP	DATE: 10-31-94	CHECKED: JAM	DATE: 11-7-94

$bh = 18'' \times 30''$ $d = 30-3-1 = 26''$

$F = 1.014$

$K_n = 287.8/1.014 = 284$ $\rho = .0055$

$A_s = 2.57 in^2$. 4 #8 Bott.

$\phi V_c = 18 \times 26 \times 2\sqrt{4000} \times 0.85$ 2 #7 Top Cont.

$= 50.32^k > V_u = 47.4^k$. #4 @ 12" □ thru out.

VALVE VAULT:

TOP SLAB:

$l = 7'-6''$
$1'-6''$
$9'-0''$

w = 12" slab = 150 psf 300 psf 24"
LL: 2DL = 300 $d = 21''$
or H-20 Loading. $F = 0.441$

$M = 0.150 (0.300) \times 9.0^2/8 = 1.5^{k/ft}$ (3.0) × 1.3 ✓

$0.900 \times 9.0 \times 1.3 = 10.5$ × 1.3 × 1.67

(13.5) $12.0^{k/ft}$ × 1.3 × 1.67 = $25.7^{k/ft}$ (26.7)

$K_n = 318$, $\rho = 0.0062$ $A_s = 0.66 in^2$ #6@8 Bott. (Trans)

$K_n = (66)$ ($\rho = 0.0033$) ($A_s = 0.83$ #5@8 Top EW and Bott (Longit).

Use ⟶ #7@8 Bott. Transv)

Beams:

$l = 21'-9''$ c/c.

w = DL: 12" slab (300) 150 × 3.75' = $0.56^{k/ft}$ (1.12)
18" × 24" Bm = 0.45
Hatch @ 30 psf × 2.55 = 0.08

} 1.09 × 1.4 = $1.53^{k/ft}$
(1.65) (2.31)

LL @ 300 psf (3.75 + 1.5 + 2.56) = $2.34^{k/ft}$ × 1.7 = $3.98^{k/ft}$

$M_u = \frac{5.51 \times 21.75^2}{8}$ (6.29) = 325.8^{k} (372.) × 1.3 = (484) × 1.3 = 424 $w = 3.43^{k/ft}$ $w_u = 5.51^{k/ft}$

$V_u = 57.2^k$ (65.3) $V_{ud} = 47.56^k$ (54.29) 24" (54.13^k) (b = 24") $d = 21''$ (6.29)

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 18 \times 21 = 40.6^k$ $F = 0.662$ (0.882)

$\phi V_s = 7.0^k$ #4 □ @ 10" c/c thruout ✓ $K_n = 640.$ (549)

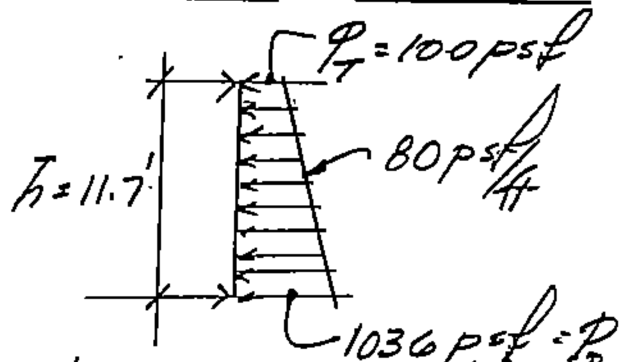
$\phi V_s / k_w d = 0.016$ $\rho = 0.0135$ (0.0173)

$A_s = 5.10 in^2$ 7 #8 Bott
(5.69 in²) 2 #8 Top

(See Sht. 10 - Top slab, t = 24" w/o Bms) (8 #8 Bott in 24" width

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON		JOB NO. 3904-00 0101
	SUBJECT: STD PUMP STN - 3 PUMPS - 2000 - 5300 GPM/P		SHEET 9
	DESIGNED: NMP	DATE: 10-31-94	CHECKED: JAM — DATE: 11-7-94

VALVE VAULT: WALLS: $t = 12''$ $h = 1'6'' + 9'2\frac{1}{2}'' + 1'0'' = 11'8\frac{1}{2}'' = 11.7'$



$P_T/P_B = 0.096 \le 0.10.$ $P = \frac{100+1036}{2} \times 11.7 = 6.65^k$

$M_{max} = \frac{6.65 \times 11.7}{7.82} = 9.9^{k}/ft$

$M_u = 1.7 \times 1.3 \times 9.9 = 22.0^{k}/ft$

$t = 12''$ $d = 12'' - 2\frac{1}{2}'' - \frac{1}{2}'' = 9''$

$F = 0.081$

$K_n = 272$

$\rho = 0.0053$

$A_s = 0.57\,in^2/ft$

#6 @ 8'' Vert I.F.

#5 @ 8 Vert OF.

#4 @ 12 Hor EF.

$t = 16''$ $d = 13''$ $F = 0.169$

$K_n = 130$ $\rho = 0.0025$

$\rho_{min} = 0.0033$

$A_{s\,min} = 0.51\,in^2$ #6 @ 8'' (0.66). Vert IF.

BASE SLAB:

Loads Top slab DL	= 150 psf	× 1.4	= 210
" LL	= 300	× 1.7	= 510
Walls $\frac{(2 \times 20.5 + 20.75) \times 10.20 \times 150}{22.75 \times 20.5}$	= 202 psf	× 1.4	= 284
			1004 × 1.3

$w_u = 1305\,psf$

$A = 19.50$

$B = 21.75$ $m = 0.90$

$M_A = 1.31 \times 0.045 \times 19.5^2 = 22.4^{k}/ft$

$M_B = 0.029 \times 1.31 \times 21.75^2 = 18.0^{k}/ft$

$d = 16 - 3'' - 1'' = 12''$

$F = 0.144$

$K_{nA} = 156$, $\rho_A = 0.0031$, $\rho_{min} = 0.0033$ $A_s = 0.48\,in^2$

$K_{nB} = 125$, $\rho_B = 0.0024$

#5 @ 8'' Top EW

#5 @ 12 Bott. EW -

Check Bouyancy:

h_w = Top slab = 2-0½ ; wall = 9-2½ ; Base = 1-6 $\}$ = 12'-8½'' uplift = 62.4 × 12.70' = 792 psf ↑

DL = 24'' slab = 300

12'' walls = 202

18'' Base slab = 225

645 psf

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF Houston		JOB NO. 3904 [illegible] 01
SUBJECT: ST.D.PS. - 3 PUMPS 2000-5300 GPM/Ea		SHEET 10.
DESIGNED: NMP	DATE: 11-2-94	CHECKED: JAM, DATE: 11-7-94

Consider 1'-0" ftg three side
Bouyant wt of Ledge Soil

$(2\times 20.5 + 24.75)\times 11.7 \times 0.060 = \dfrac{46.2^k}{20.5\times 22.75} = 100ps$

$\Sigma W_{DL} = 645 + 100 = 745\ psf \downarrow < 792\ psf \uparrow$

for F.S. against bouyancy = 1.20

$\Delta DL = (1.2\times 792 - 745) = 205\ psf \downarrow$

✓ Extend base slab 2'-0 beyound 1'-4" thick walls

Soil wt = $(2\times 20.5 + 27.58)\times 11.7\times 2\times .06 = \dfrac{96.3^k}{20.5\times 23.42} = 201\ psf.$

1'-4" wall $= (2\times 20.5 + 23.42)\times 9.2'\times 1.33\times 150 = \dfrac{118.2^k}{20.50\times 23.42} = 246p$

$\Sigma W_{DL} =$ 300.
246.
225.
201.
972 psf

$FS = \dfrac{972}{792} = 1.23$

Alt: Top Slab w/o Beams:

$l = 21'\text{-}9''$ (max)

Use

$w = 24''$ slab $= 300\ psf \times 1.4 = 420$

LL $= 300\ psf \times 1.7 = 510$

$w = 600\ psf$ $\quad W_u = 930\ psf$

$M_{DL} = 0.30\times 21.75^2/8 = 17.7\ ^{k}/ft \times 1.0\times 1.3 = 23.0\ ^{k}/ft$ ✓

$M_{LL} = 0.30\times 21.75^2/8 = 17.7\ ^{k}/ft$ — Sanit. factor

or $0.9\times 21.75\times 1.3 = 25.4\ ^{k}/ft \times 1.67\times 1.3 = 55.1\ ^{k}/ft$

Impact — AASHTO FACTORS

$78.1\ ^{k}/ft$

$d = 21''$ $F = 0.441$ $K_n = 177$

$\rho = 0.0033$

$A_s = 0.84\ in^2$ #7@8" Bott parallel to Hatch opngs.

#5@8" Dist. Reinf.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.				
PROJECT	CITY OF HOUSTON, TX			JOB NO. 3904-00 0101
SUBJECT	STD. P.S. - 3 PUMPS - 2000-5300 GPM EA.			SHEET 11
DESIGNED NMP	DATE 11-2-94	CHECKED JAM		DATE 11-7-94

TOP SLAB: BEAMS BETWEEN HATCHES:

$b \times t = 11'' \times 24''$

$b \times t = 16'' \times 24.$ $\quad d = 20''$

$\ell = \left.\begin{matrix} 5'-0\frac{1}{2} \\ 2-0 \end{matrix}\right\} = 7'-0\frac{1}{2}''$ $\quad F = 0.400 \times 1.33 = 0.532$

$\times 0.92 = 0.368$

$W = DL \; @ 300 psf \times 1.33' = 400 \times 1.4 = 560 plf.$

$LL \; @ 300 psf \times 3.58' = 1074 \times 1.7 = \underline{1826}$ "

$W_u \; 2386 plf$

$M_u = 2.39 \times 7.04^2/8 = 14.8^{1k} \times 1.3 = 19.2^{1k}$

$V_u = 2.38 \times 5.04/2 = 6.0^k \langle \phi V_c > or \; 1.2 + 20.8 = 22.0^k$

108 psi. $\quad \phi V_c = 0.85 \times 2\sqrt{4000} \times 16 \times 20 = 34.4^k$

$b = 11''$ $\quad \times 11 \times 20 = 23.65^k.$

$F = 0.368, K_m = 52 \quad \rho_{min} = 0.0033$

$A_s = 1.06 in^2 \quad \underline{2\#8 \; T \& \; BOTT \times 9'-0'' Lg.}$

$\#3 \square @ 8''$ STIRRUPS.

Valve Pad:

$A = 15'$

$B = 18'-6''$ $\quad m = 0.81.$

$W_{DL} = 150 psf \quad 175$

$W_{LL} = \underline{150 psf} \quad \underline{255}$

$W_{Tot} = 300 psf \quad W_{u_{TOT}} \; 430 psf$

$M_A = 0.061 \times 0.43 \times 15^2 = 5.9^{1k}/ft$

$M_B = 0.023 \times 0.43 \times 18.5^2 = 3.4^{1k}/ft$

$d = 12'' - 3'' - 1'' = 8''$

$F = 0.064$

$V_A = \frac{0.71}{2} \times 15 \times 0.43 = 2.29^k/ft$

$0.30 = 1.6^k/ft$

$K_{n_A} = 92 \quad \rho_{min} = 0.0033$

$A_s = 0.32 in^2/ft.$

Gr. Wall $\; 1.0 \times 2.5 \times 0.150 = \underline{0.38}$

$1.98 k/ft$

#5 @ 12" Bott EW

$f_{bearing} = 1.98 ksf \langle 3.0 ksf$ / allowable

#5 @ 8 Top EW -

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	HOUSTON, TX STDS PROJECT LP, SSC PUMP STN-EZ		3921-00 JOB NO. 0101
	3 PUMPS @ 2000-5300 GPM SUBJECT LOW PROFILE - SECURED		1 of 7 SHEET
	CEO DESIGNED	11/14/95 DATE	NMP CHECKED / 11-21-95 DATE

VALVE VAULT : 21'-2" X 24'-9" X 13'-0" w/ 2'-0" walls

GRATING : FRP = 25 psf
LL = 150 psf
175 psf

- DESIGN FOR CRITICAL BEAM - B-2

$L = 20'-9"$

$w = 175 \text{ psf} * \left(\frac{3.0' + 4.5'}{2}\right) = 656 \text{ p/f}$

BEAM WT SAY = 44
700 p/f

$M = \frac{wl^2}{8} = \frac{.7 * 20.75^2}{8} = 37.7\ 'k$

$W = wl = .7 * 20.75 = 14.53^k$

$V = w(l/2) = .7 * 20.75/2 = 7.27^k$

FROM ALLOW. M IN BEAM CHART W 10x33 $M_R = 50\ 'k$

$\Delta_{approx} = \frac{0.98 \times 14.53}{28} = 0.51" = \frac{L}{488}$ $l_u = 20.75$

SINGLE PLATE SHEAR CONNECTION, TBL X-A PG 4-54

3/8" PL x 6" x 6" w/ 13/16 x 1 7/8" LONG SLOTTED HOLES FOR 2 - 3/4" Φ A325 BOLTS

(STEEL) $V_{allow} = 8.2^k > V = 7.27^k$

REF. PCI 3RD ED. TBL 6.20.7

(CONC) $V_u = 7.27^k * 1.7 = 12.4^k \ll \phi V_c = 12.2^k/\text{STUD}$ 2 - 3/4" STUDS = 24.4^k

WALL FACE PL = 3/8" x 6" x 8" W/ 2 - 3/4" Φ 6" LONG STUDS

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, Tx Stds			JOB NO. 3921-00 0101
	SUBJECT: 3 Pumps @ 2000-5300 GPM LOW PROFILE - SECURED			SHEET 2 of 7
	DESIGNED: CEO	DATE: 11-14-95	CHECKED: NMP	DATE: 11-21-95

VALVE VAULT

· DESIGN FOR CRITICAL BEAM : B-4

$L = 20'-9"$

$w = 175 \text{ psf} * \frac{(5.17' + 5.5')}{2} = 934$

BEAM WT $= \underline{56}$

990 P/F

$M = \frac{0.99 * 20.75^2}{8} = 53.3\ '^k$

$W = 0.99 * 20.75 = 20.6^k$

$V = \qquad 10.3^k$

CHOOSE W14×38 $\qquad M_R = 54.25^k$

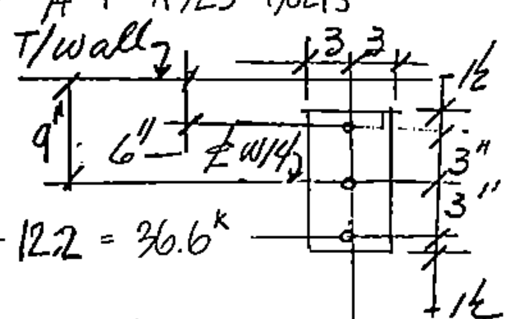
$\ell_n = 20.75'$

$\Delta_{approx} = \frac{0.70 * 20.6}{43} = 0.34" < L$

SINGLE PLATE SHEAR CONNECTION TBL X-B PG 4-54

3/8" PL × 6 × 9 w/ 13/16 × 1 7/8 LONG SLOTTED HOLES FOR 3-3/4"⌀ A325 BOLTS

(STEEL $\qquad V_{allow} = 16.3^k > V = 10.3^k$



REF: PCI 3RD ED. TBL 620.7

(CONC) $\qquad V_u = 10.3 \times 1.7 = 17.5^k \ll \phi V_c = 3 * 12.2 = 36.6^k$

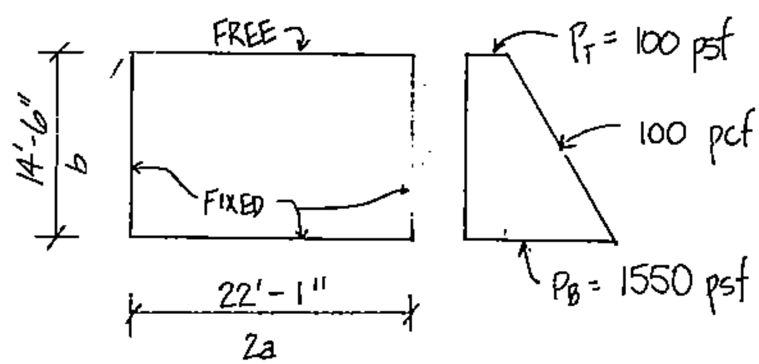
WALL FACE PL = 3/8" × 6 × 9 w/ 3-3/4"⌀ × 6" LONG STUDS

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: HOUSTON, TX STDS			JOB NO. 3921-00 0101
SUBJECT: 3 PUMPS @ 2000-5300 GPM LOW PROFILE-SECURED			SHEET 3 of 7
DESIGNED: CEO	DATE: 11-14-95	CHECKED: NMP	DATE: 11-27-95

PIT WALLS REF: BOR, EM No 27

END PANEL = 22'-1" × 14'-6"



$a/b = \frac{22.08}{2 \times 14.5} \approx 0.75$

$P_T b^2 = 0.1(14.5)^2 = 21.03^{\,k}$

$P_T b = 1.45'^{k}$

$P_B b^2 = 1.45(14.5)^2 = 304.9^{k}$

$P_B b = 1.45(14.5) = 21.02'^{k}$

$M_x^+ = (0.0807 * 21.03) + (0.0214 * 304.9) = 8.22\ {}^{'k}/_{ft} \times 1.7 = M_{u_H}^+ = 14.0^{'k}$

$M_x^- = (0.1788 * 21.03) + (0.0433 * 304.9) = 16.96 \times 1.7 = M_{u_{HORZ}}^- = 28.9^{'k}$

$M_y^- = (0.1212 * 21.03) + (0.0584 * 304.9) = 20.35 \times 1.7 = 34.6^{'k}$

$M_y^+ = (0.0245 * 21.03) + (0.0143 * 304.9) = 4.88 \times 1.7 = 8.3^{'k}$

$d_V = 16 - 2 - \frac{1}{2} = 13.5"$ $F_V = 0.182$

$d_H = 16 - 3 - \frac{1}{2} = 12.5"$ $F_H = 0.156$

CODE sect 10.5.2

$K_H^+ = M_u/F_H = 90$ $\rho_H^+ = 0.0017$ (0.0023) $A_{S\,MIN}^+ = \rho_H b d_H * 4/3 = 0.53$ (0.35) #6 @ 14" H, IF

$K_H^- = 185$ $\rho_H^- = 0.0035$ (0.0047) $A_{SH}^- = 0.58$ (0.71) #6 @ 7" H OF @ INTERS

$K_V^+ = M_u/F_V = 46$ $\rho_V^+ = 0.0013$ (0.0017) $A_{SV\,MIN}^+ = \rho_V * b * d_V = 0.53$ (0.27) #6 @ 14" Vert IF

$K_V^- = 190$ $\rho_V^- = 0.0036$ (0.0048) $A_{SV}^- = 0.58$ (0.76) #6 @ 7" Vert Bio ½ OF

$\rho_{min} = 0.0033$ $A_{S\,V\,min} = 0.53\ in^2$

$A_{S\,H\,min} = 0.50\ in^2$

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.			
PROJECT: Houston, Tx, stds			JOB NO. 3921-00
SUBJECT: 3pumps @ 2000-5300 GPM / LP secured			SHEET 4 OF 7
DESIGNED: NMP	DATE: 4-26-96	CHECKED	DATE

Buoyancy: Consider Structure right of Exp. Joint:

24" Walls: $2 \times 13' \times 20.67' \times 2.0 \times 0.150 = 161.2^k$

$1 \times 13 \times 20.75 \times 2.0 \times 0.150 = 80.9$

30" Base Slab: $24.17 \times 31.75 \times 2.5 \times 0.150 = 287.8$

$W_c = 529.9^k$

3'-6" Ftg Soil: $2 \times 3.5 \times 24.17 \times 12.5 \times 0.120 = 253.8^k$

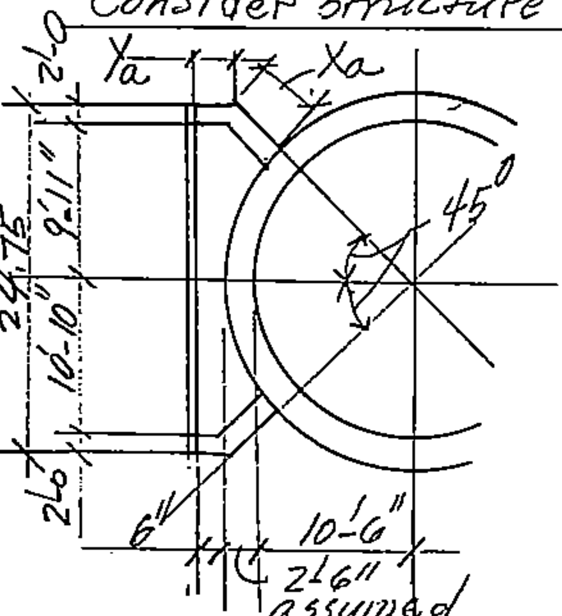
$1 \times 3.5 \times 24.75 \times 12.5 \times 0.120 = 129.9$

$W_s = 383.7^k$

Uplift: $24.17 \times 31.75 \times 15.5 \times 0.062 = 737.5^k$

$$\frac{529.9}{1.10} + \frac{383.7}{1.50} = 481.7 + 255.8 = 737.5^k = F_u.$$

Consider structure between Exp. Jt and Wet Well:



$X_{ave} = \dfrac{24.75}{2 \times 0.707} - 13.0 = 4.50'$

$Y_a = 13.5 - 12.38 = 1.12$

Wall l = 5.62 ft

Top Slab area:

$1.12 \times 24.75 = 27.7$

$12.38 \times 12.38 = 153.3$

$-\pi \times 13^2/4 = -132.7$

$48.3\ ft^2$

Base Slab area: $48.3\ ft +$

$+ 2 \times 5.62 \times 3.5 = 87.6\ ft^2$

Dead Loads:

Top Slab: $48.3 \times 2 \times 0.150 = 14.5^k$

Walls: $2 \times 2 \times 5.62 \times 11 \times 0.150 = 37.1$

Base slab: $87.6 \times 2.5 \times 0.150 = 32.9$

$W_c = 84.5^k$

3'-6" Ftg Soil: $2 \times 3.5 \times 5.62 \times 12.5 \times 0.120 = 59.0 = W_s$

Uplift: $87.6 \times 15.5 \times 0.062 = 84.2^k = F_u$

$$\frac{84.5}{1.10} + \frac{59.0}{1.50} = 76.8 + 39.3 = 116.1^k > F_u$$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS			JOB NO. 3921-00 1010
	SUBJECT: 3 PUMPS @ 2000-5300 GPM LOW PROFILE - SECURED			SHEET 5 of 7
	DESIGNED: CEO	DATE: 11-16-95	CHECKED: NMP	DATE: 11-27-95

BRACKET FROM WET WELL WALL:

CONSIDER 5' WIDE BASE SLAB & 5'-0" OF WALLS FROM VAULT SUPPORTED ON TO BRACKET.

P_{SLAB} = 1'-6" SLAB @ 225 psf * 5' = 1125 #/ft
LL @ 150 psf * 5' = 750
1875 #/ft

$P_{WALL} = 0.150 \times 13' \times 5' \times 1.33 = 17.29^k$

w = 2'-6" SLAB = 375 psf

ASSUME WET WELL t = 2'

$\ell_{min} = 1'=0"$

$\ell_{Max} = (12.5' - 12.5 \cos 45) + 1.0' = 4.66'$

$L_{AVE} = 2.83'$

$M_{AVE} = 0.375 * 2.83^2/2 = 1.50$ 'k/ft
1.875 * 2.83 = 5.31
6.81 'k/ft

$M_{MAX} = 0.375 * 4.66^2/2 = 4.07$ 'k/ft
1.875 * 4.66 = 8.74 'k/ft
12.81 'k/ft * 1.7 = 21.78 'k/ft

d = 30" - 2 - 1 = 27" b = 12

F = 0.729 K_n = 30 ρ_{min} = 0.0018 $A_s = 0.58 in^2/ft$ #6 @ 9" T (0.59)

WALL AS BRACKET : L = 4.6'

$P_{WALL} = 17.29^k \downarrow$ w = 2.6 k/ft ↓

OR

$P_{UPLIFT} = 83.2^k \uparrow$

$M_{DL} = 17.29 \times 4.6 = 79.5$ 'k
$2.6 \times 4.6^2/2 = 27.5$
107.0 'k

$M_{UPLIFT} = 83.2^k \times 4.6 = 382.7$ 'k

Ref: PCA - "Simplified Design", Shear Wall, pg 6-13.

$M_{u_1} = 1.4 \times 107 = 150^{k}$

$M_{u_2} = 1.7 \times 382.7 = 651^{k}$ controls

$\phi M_n = \phi [0.5 A_{st} f_y l_w (1 + \frac{P_u}{A_{st} f_y})(1 - \frac{c}{l_w})]$

where $\phi = 0.9$

$A_{st} = \#6@12EF = 0.44 \times 2 \times 13 = 11.44 \text{ in}^2$

$l_w = 13 \times 12 = 156''$ $h = 24''$, wall thickness

$P_u = 0$

$\frac{c}{l_w} = \frac{\omega + \alpha}{2\omega + 0.85\beta_1}$ where $\alpha = 0$ for $P_u = 0$,

$\beta_1 = 0.85$ for $f'_c = 4000$

$= \frac{0.046}{2 \times 0.046 + 0.722}$

$= 0.057$

$\omega = \left(\frac{A_{st}}{l_w h}\right) \frac{f_y}{f'_c} = \frac{11.44 \times 60}{156 \times 24 \times 4} = 0.046$

$\phi M_n = 0.90 \times 0.5 \times 11.44 \times 60 \times 156 \times 0.94 / 12$

$= 3774^{k} \gg 651^{k}$

Base Slab:

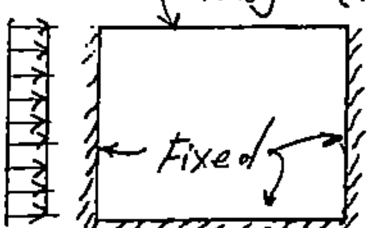
Net Uplift $= 15.5 \times 0.0624 = 0.967$ ksf

$- 2.50 \times 0.150 = 0.375$

$p = 0.592$ ksf

Hinged (thru dwls).

Ref: BOR EM.



Fixed

$b = 19'-4''$ $pb = 11.4$ $pb^2 = 221.$ $a/b = 0.57 < \begin{matrix} 0.5 \\ 0.75 \end{matrix}$

$2a = 22'-1''$

$M_x^- = 0.0695 \times 221. = 15.4^{k}$ $M_{ux}^- = 26.2^{k}$

$M_x^+ = 0.0263 \times 221. = 5.8$ $M_{ux}^+ = 9.9$

$t = 30''$ $F = 0.529$

$M_y^- = 0.0898 \times 221. = 19.8$ $M_{uy}^- = 33.7$

$d_{min} = 28 - 3 - 2 = 23''$

$M_y^+ = 0.0473 \times 221. = 10.5^{k}$ $M_{uy}^+ = 17.9^{k}$

$\rho_{min} = 0.0018$

$A_{s\,min} = 0.50 \text{ in}^2/\text{ft}$

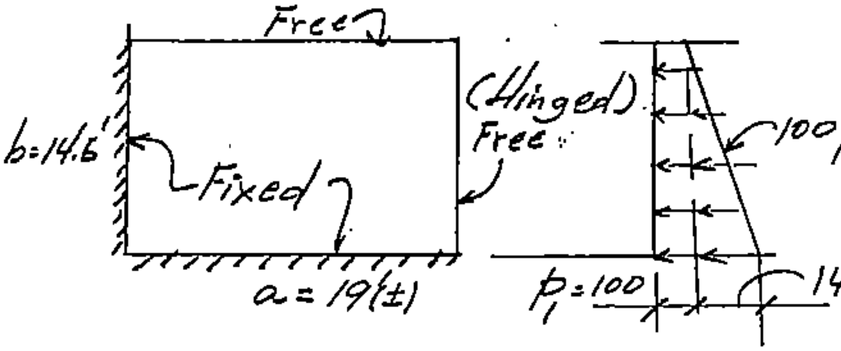
$\left.\begin{matrix} K_{nx}^- = 50 \\ K_{nx}^+ = 19 \\ K_{ny}^- = 64 \\ K_{ny}^+ = 34 \end{matrix}\right\}$ $A_{s\,min} = 0.50 \text{ in}^2/\text{ft}$ average ($\pm 10\%$ Distr.) - $<$ 0.45 in²/ft #6@12 Bot/Top; 0.56 in²/ft #6@7" at wall - Bott.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: Houston Tx, std.			JOB NO. 3921-00 0101
SUBJECT: 3 pumps at 2000-5300 GPM			SHEET 7 of 7
DESIGNED: NMP	DATE: 11-28-95 5-3-96	CHECKED	DATE

Valve Pit - Side walls: Ref: BOR, EM. No. 27

$a/b = 19/14.5 = 1.31 \approx 1.00$



$p_1 b = 0.1 \times 14.5 = 1.5$
$p_1 b^2 = 0.1 \times 14.5^2 = 21.$
$p_2 b = 1.45 \times 14.5 = 21.$
$p_2 b^2 = 1.45 \times 14.5^2 = 305$

$M_x^- = 0.2949 \times 21 + .0662 \times 305 = 26.4^{1k}/ft$ $\quad M_{ux}^- = 44.9^{1k}/ft$
$M_x^+ = 0.0324 \times 21 + 0.0077 \times 305 = 3.0$ $\quad = 5.1$
$* M_y^- = 0.2949 \times 21 + 0.1157 \times 305 = 41.5^{1k}$ $\quad M_{uy}^- = 70.5^{1k}/ft$
$M_y^+ = 0.0324 \times 21 + 0.0172 \times 305 = 5.9^{1k}$ $\quad = 10.0^{1k}/ft$

$t = 24''$ $\quad d_H = 24 - 3\frac{1}{2} - \frac{1}{2}'' = 20.0$ $\quad F = 0.40$
$d_V = 24 - 2\frac{1}{2} - \frac{1}{2} = 21.0''$ $\quad F = 0.44$

$K_{nx}^- = 112.$ $\quad \rho_H^- = 0.0021$ $\quad A_{sH}^- = 0.50\ in^2/ft$ $\quad$ #6@7" @ Inters.
$K_{nx}^+ = 13.$ $\quad \rho_H^+ = 0.0015$ $\quad A_{sH}^+ = 0.36\ in^2/ft$ $\quad$ #6@14 Cont.
(*) $K_{ny}^- = 160$ $\quad \rho_V^- = 0.0030$ $\quad A_{sV}^- = 0.76\ in^2/ft$ $\quad$ #6@7" Vert. dwls OF.
$K_{ny}^+ = 23$ $\quad \rho_V^+ = 0.0015$ $\quad A_{sV}^+ = 0.38\ in^2/ft$ $\quad$ #6@14" Vert IF.
Use this.

(*) Consider Vert. Edges Hinged: $a/b = \frac{19}{2 \times 14.5} = 0.66$
$M_y^- = 0.2135 \times 21 + 0.0871 \times 305 = 31.0^{1k}/ft$ $\quad M_u = 52.8^{1k}/ft$
$K_{ny}^- = 120$ $\quad \rho = 0.0023$ $\quad A_{sy}^- = 0.58\ in^2/ft$ $\quad$ #6@9" OF dwls.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, TX STD LP-55'C- Pump STN- F2		JOB NO. 3921-00 0101
	SUBJECT 4 Pumps- 500-2800 GPM Secure Site Pump Stn		SHEET 1 of 4
	DESIGNED NMP	DATE 11-30-95	CHECKED	DATE

VALVE VAULT: 15'-0 x 25'-6" x 8'-8" walls, t = 12":

Grating - FRP wt. = 25 PSF.

Live Load = 150 psf.

W = 175 psf

Support Beams:

Beam B1 - L = 23'-6"

$w = 175\left(\frac{4.33+3.17}{2}\right) = 656$ plf

wt. of Bm = 44 " (assumed).

700 plf

$M = 0.7 \times 23.5^2/8 = 48.3^k$

$V = 0.7 \times 23.5/2 = 8.2^k$

$W = 16.4^k$

W10X39 $l_u = 23.5'$

$M_R = 63^k$

$\Delta_{W12} = \frac{1.08 \times 16.4}{23.0} = 0.77$ in $= \frac{L}{366}$

W12X26 $l_u = 12'$

Use $M_R = 50^k$

Provide 3-3/4"ϕ Bolt Conn.

Beam B2: L = 23'-6"

$w = 175\left(\frac{3.17+2.75}{2}\right) = 518$ plf

wt. of Bm 32

550

$M = \frac{0.55 \times 23.5^2}{8} = 38^k$

$V = 0.55 \times 23.5/2 = 6.46^k$

$W = 0.55 \times 23.5 = 12.93^k$

Use. Provide 2-3/4"ϕ Bolt Conn.

W8X24 $l_u = 12'$

$M_R = 39^k$

$\Delta_{W8} = \frac{5 \times 12.93^k \times (23.5)^3 \times 1728}{384 \times 29 \times 10^3 \times 82.8} = 1.57" = \frac{L}{180}$ ok

$\Delta_{W10} = \frac{5 \times 12.93\ (23.5 \times 12)^3}{384 \times 29 \times 10^3 \times 170} = 0.77" = \frac{L}{366}$

W10X33 $l_u = 23.5'$

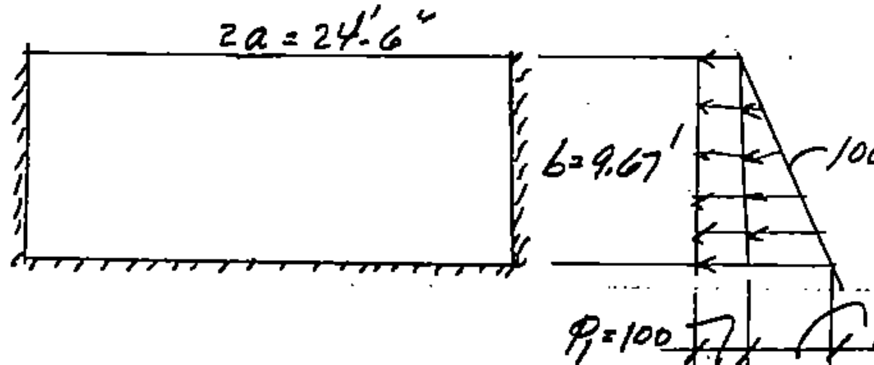
$M_R = 43^k$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston Tx Stds.		JOB NO. 3921-00 0101
	SUBJECT: 4 Pumps - 500-2500 GPM		SHEET 2 of 4
	DESIGNED: NMP	DATE: 12-4-95	CHECKED	DATE

VALVE PIT WALLS:

Back Wall:

$a/b = \frac{24.5}{2 \times 9.67} = 1.26$



$p_1 b = 1.$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4$

$M_x^- = 0.2959 \times 9.4 + 0.0751 \times 90.4 = 9.57^k$ $M_u = 16.3^k/ft$

$M_x^+ = 0.0937 \times 9.4 + 0.0257 \times 90.4 = 3.2^k$ $= 5.4$

$M_y^- = 0.2776 \times 9.4 + 0.1054 \times 90.4 = 12.1$ $= 20.7^k/ft$

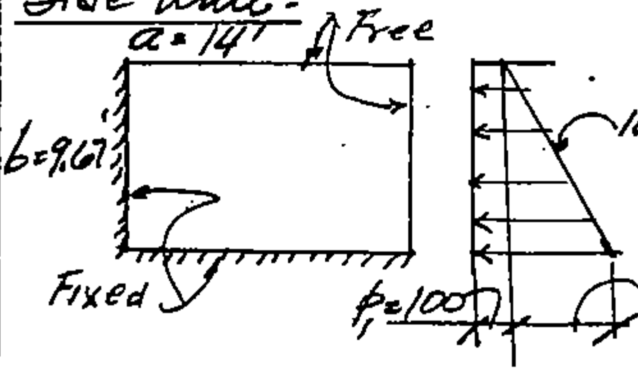
$M_y^+ = 0.0206 \times 9.4 + 0.0127 \times 90.4 = 1.3^k$ $= 2.2$

$t = 12$" wall, $d_H = 8.5$" $F_H = 0.07$
$d_V = 9.5$" $F_V = 0.09$

$K_H^- = 233.$ $\rho = 0.0045$ $A_{sH}^- = 0.46\ in^2/ft$ #5@12"HOF. @ Corner
$K_H^+ = 77.$ $\rho_{min} = 0.0033$ $A_{sH}^+ = 0.34\ in^2/ft$ #5@12 HEF.
$K_V^- = 230$ $\rho = 0.0044$ $A_{sV}^- = 0.50\ in^2/ft$ #5@6"VOF dwls
$K_V^+ = 24$ $\rho_{min} = 0.0033$ $A_s^+ = 0.38\ in^2/ft$ #5@12 VEF.

Side Wall:

$a/b = 14/9.67 = 1.45 \rightarrow$ Use $= 1.00$



$p_1 b = 1.0$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS		JOB NO. 3921-00 0101
	SUBJECT: 4 PUMPS - 500-2600 GPM		SHEET 3 OF 4
	DESIGNED: NMP	DATE: 12-4-95	CHECKED	DATE

$M_x^- = 0.2949 \times 9.4 + 0.0662 \times 90.4 = 8.8^{k/ft}$, $M_u = 14.9^{k/ft}$

$M_x^+ = 0.0324 \times 9.4 + 0.0077 \times 90.4 = 1.0$ $= 1.7$

$M_y^- = 0.2949 \times 9.4 + 0.1157 \times 90.4 = 14.2$ $M_u = 24.2^{k/ft}$

$M_y^+ = 0.0324 \times 9.4 + 0.0172 \times 90.4 = 1.9$ $= 3.2^{k/ft}$

$K_H^- = 213.$ $\rho = 0.0041$ $A_{sH}^- = 0.43$ #5@12 HOF @ Corner

$K_H^+ = 24.$ $\rho_{min} = 0.0033$ $= 0.34$ #5@12 HEF.

$K_V^- = 269.$ $\rho = 0.0052$ $A_{sV}^- = 0.59$ #5@6" OF DWLs

$K_V^+ = 36.$ $\rho_{min} = 0.0033$ $= 0.38$ #5@12 VEF.

Base Slab:

DEAD LOADS: 12" walls $2 \times 14.5 \times 8.67 \times 0.150 = 37.7^k$

$1 \times 23.5 \times 8.67 \times 0.150 = 30.6$

16" Base slab $14.5 \times 25.5 \times 0.200 = 74.0$

142.3^k

2'-0 Ftg. Soil wt = $2 \times 2' \times 16.5' \times 10.0' \times 0.06 = 39.6$

$1 \times 2' \times 23.5 \times 10.0 \times 0.06 = 28.2$

$240.1^k \downarrow$

Uplift = $14.5' \times 25.5' \times 10' \times 0.0624 = 230.7^k \uparrow$

F.S against Uplift = $240.1 / 230.7 = 1.04$

Resisting Force required = $1.25 \times 230.7 = 288.4^k$

$- 240.1$

or Force transfered to wetwell $48.3^k \uparrow$

by Wall-Bracket, $\frac{48.3}{2} = 24.2^k \uparrow$ Each wall.

Assume wet-well wall $t = 2'-0''$

Wall backet Length = $\sqrt{13.0^2 + 12.5^2} - 12.5' = 5.53'$

$M_{Br} = 24.2 \times 5.53' = 134^{k}$

$M_u = 1.7 \times 134 = 228^{k}$

Wall bracket $t = 12''$ w/ #6@12 EFEW Reinf.

Ref: PCA "Simplified Design" Shear walls pg 6-13.

$$\phi M_n = \phi \left[0.5 A_{st} f_y l_w \left(1 + \frac{P_u}{A_{st} f_y}\right)\left(1 - \frac{c}{l_w}\right)\right]$$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: Houston, Tx STDS			JOB NO. 3921-00 0101
SUBJECT: 4 Pumps - 500-2500 GPM EA.			SHEET 4 of 4
DESIGNED: NMP	DATE: 12-4-95	CHECKED	DATE

$P_u = 0$

$A_{st} = 0.44 \times 2 \times 8 = 7.04 \text{ in}^2$

$l_w = 8'8" = 104"$

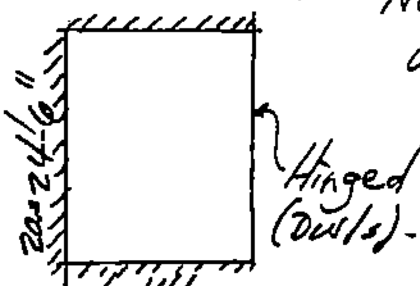
$\omega = \dfrac{A_{st} f_y}{l_w h f_c'} = \dfrac{7.04 \times 60}{104 \times 12 \times 4} = 0.085$

$\dfrac{c}{l_w} = \dfrac{\omega}{2\omega + 0.85\beta_1}$ $\quad \beta_1 = 0.85$ for $f_c' = 4000$ psi

$= \dfrac{0.085}{0.17 + 0.72} = 0.095$

$\phi M_n = 0.90\left[\dfrac{0.5 \times 7.04 \times 60 \times 104 \times 0.905}{12}\right] = 1490^{1k} \gg M_u = 228^{1k}$

BASE SLAB:



Net Uplift $= 0.062 \times 10' - 1.33 \times 0.150 = 0.420$ ksf

$a/b = \dfrac{24.5}{2 \times 14} = 0.88$

$pb = 0.42 \times 14 = 5.88$

$pb^2 = 0.42 \times 14^2 = 82.3$

$M_x^- = 0.0680 \times 82.3 = 5.6^{1k}$ $\quad M_u = 9.6^{1k}$

$M_x^+ = 0.0249 \times 82.3 = 2.0^{1k}$ $\quad = 3.4$

$M_y^- = 0.0996 \times 82.3 = 8.2$ $\quad = 13.9^{1k}$

$M_y^+ = 0.0540 \times 82.3 = 4.4$ $\quad = 7.6$

$t = 16"$ $\quad d_T = 16 - 2 - \frac{1}{2} - 1 = 12.5"$ $\quad F = 0.156$

$d_B = 16 - 3 - \frac{1}{2} - 1 = 11.5$ $\quad F = 0.132$

$K_x^- = 73$ $\quad \rho_{min} = 0.0018$ $\quad A_s = 0.35 \text{ in}^2/\text{ft}$ $\quad$ #5@6 from Dwls.

$K_y^- = 105$ $\quad$ (Gross area).

$K_y^+ = 48$ $\quad A_s = 0.35 \text{ in}^2/\text{ft}$ $\quad$ #5@12 EW. Bottom

$V_{y\,Hinge} = 0.3922 \times 5.88 = 2.31^k/\text{ft}$ ↑ $\quad V_u = 3.92^k/\text{ft}$ ↑ $\quad$ #5@8 EW Top -

$= 0.2735 \times 5.88 = 1.6^k/\text{ft}$ ↑ $\quad M_u = 2.0^{1k}/\text{ft}$ $\quad V_u = 2.73^k/\text{ft}$ $\quad M_u = 8.2^{1k}/\text{ft}$

$K_n = 53$ $\quad \rho_{min} = 0.0018$ $\quad A_s = 0.35 \text{ in}^2/\text{ft}$ $\quad$ #6@12 Dwls from Wet Well

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON			JOB NO. 3904-000
	SUBJECT: STD. LIFT STATION – 4 Pumps 500 – 2500 GPM Ea.			SHEET 1
	DESIGNED: NMP	DATE: 2-9-95	CHECKED:	DATE:

WET WELL:

TOP SLAB:

LL: Equiv. Equip. or min = 300 psf.
(No truck load considered).
DL: 24" thick slab w/o Beams = 300 psf.

$L_{max} = 2 \times \sqrt{10.5^2 - 1.89^2} + 2.0 = 22.66$ ft

$M_{DL} = 0.300 \times 22.66^2/8 = 19.3^k$, $M_{uDL} = 1.4 \times 1.3 \times 19.3 = 35.1^{k}/ft$ (1.3 = Sanit. Factor)

$M_{LL} = 19.3^k$ $M_{uLL} = 1.7 \times 1.3 \times 19.3 = 42.6^{k}/ft$

$77.7^{k}/ft$

Additional Moment due to opng: Ea. side of opng.

$\Delta M_u = 42.6 \times \frac{4.54}{2} = 96.7^k$

Consider distribution over 2' width

$\Delta M_u = 48.4^{k}/ft$

$d = 24" - 2 - \frac{1}{2}" = 21.5"$

$F = 0.462$

$K_n = 168$ $\rho = 0.0032$

$\rho_{min} = 0.0033$

$A_s = 0.85 in^2/ft$

$\Sigma M_u = 77.7 + 48.4 = 126.1^{k}/ft$

$K_n = 273$ $\rho = 0.0053$

$A_s = 1.36 in^2/ft$

#8 @ 8 Bott (1.19 in²/ft).
1#8 T&B Addl. @ Opng. ($\Sigma A_s = 1.58 in^2/ft$)
#5 @ 8" T&Bott. Temp Reinf.

VALVE VAULT:

Top SLAB:

LL: Equip - Equiv. Load or = 300 psf
(No truck Load Considered).
DL: 24" thick slab = 300 psf.

$L_{max} = 24'-6"$

Additional Load from opngs

LL: 300 psf × 2'/3.37' distribution = 178 Say 200 psf.

$W_u = 1.4 \times 1.3 \times 300 = 546$ psf
$1.7 \times 1.3 \times 500 = 1104$ psf
$\} = 1650$ psf.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON		JOB NO. 3904-00 0100
	SUBJECT: STD. LIFT STATION - 4 PUMPS 500-2500 GPM EA.		SHEET 2
	DESIGNED: NMP	DATE: 2-10-95	CHECKED / DATE

$M_u = 1.65 \times 24.5^2/8 = 124^{k/ft}$

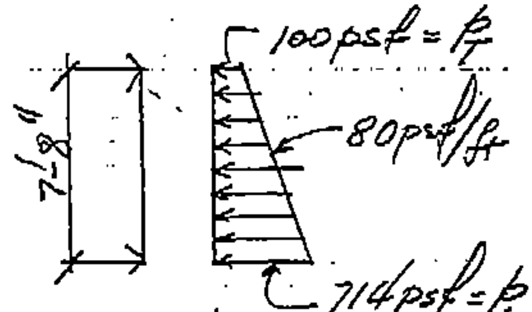
$V_{u_d} = 1.65 \times (\frac{24.5}{2} - 0.5 - 1.78) = 16.5^{k/ft}$

$V_{u_{d\,max}} = 16.5 \times \frac{4.65}{3.78} = \underline{20.4^{k/ft}} < \phi V_c = 2 \times 0.85 \sqrt{4000} \times 12 \times 21.5$
$= \underline{27.7^{k/ft}}$

$K_m = 268 \quad \rho = 0.0052$

$A_s = 1.34 \, in^2/ft$ #8@8" Bott.
1#8 T.& Bott. addl at opening.
#5@8 T.& Bott. temp. Reinf.

WALLS:
Consider flood condition with soil saturated to full height, w/ equiv. lateral pressure of 80psf



Wall Vert. span = 6'-8" + t_w = 1'-0" → 7'-8"

$p_t/p_b = 0.14$

$Q = \frac{100 + 714}{2} \times 7.67' = 3.12^k$

$M = \frac{3.12 \times 7.67'}{7.82} = 3.1^{k/ft}$

$V_T = 0.35 \times 3.12 = 1.12^{k/ft}$

$V_B = 0.65 \times 3.12 = 2.0^{k/ft}$

$M_u = 1.7 \times 1.3 \times 3.1 = 6.9^{k/ft}$

$d = 12'' - 2 - \frac{1}{2} = 9.5'' \quad F = 0.09$

$K_m = 77 \quad \rho_{min} = 0.0033 \leftarrow$ Use

$\rho = 0.0014$

$A_s = 0.38 \, in^2/ft$ #5@8" Vert. EF.
#4@12 Horiz. EF.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON	JOB NO. 3904.00 0100
	SUBJECT: STD LIFT STN- 4 PUMPS 500-750.0 GPM EA.	SHEET 3
	DESIGNED NMP · DATE 2-10-95 · CHECKED	DATE

VALVE VAULT BASE SLAB:

Loads: Top slab

$DL: \frac{(25.5 \times 17.5 - 4 \times 4.04 \times 3.83)}{25.5 \times 17.5} \times 300 = 258\ psf$

$LL: = 300$ "

Walls

$DL: \frac{(25.5+2 \times 16.5) \times 6.67 \times 1 \times 0.150}{25.5 \times 17.5} = 132$ "

Soil on 1'-6" wide Ledge

DL. $\left.\begin{array}{l} 28.5 \times 1.5 \times 9.17 \times 60\ pcf \\ 2 \times 17.5 \times 1.5 \times 9.17 \times 60\ " \end{array}\right\} = \frac{52.4^k}{25.5 \times 17.5} = 117$ "

$W_u = 1220\ psf\ (1.5) \cdot \frac{2}{7.0} = 807\ psf$

$A = 17.5'$, $B = 25.5'$ $A/B = 0.69$ Two-way slab.

$B/A = 1.46 \approx 1.5$ PCA - Rect. Tanks Pg. 2.54.

$\frac{qa^2}{1000} = \frac{0.807 \times 17.5^2}{1000} = 0.247$

$M_{Au} = 78 \times 0.247 = 19.3\ ^{k}/ft \times 1.51 \times 1.3 = 37.9\ ^{k}/ft$

$M_{Bu} = 43 \times 0.247 = 10.6\ ^{k}/ft \times 1.51 \times 1.3 = 20.8\ ^{k}/ft$

$K_{n_A} = 224$, $\rho = 0.0042$ $d = 16-2-1 = 13"$

$F = 0.169$

$A_s = 0.66 in^2$ #6@8 Top EW.

#5@8 T&B EW.

Bouyancy check

h_w = Top Slab = 2'-0"

Wall ht. = 6-8"

Base Slab = 1'-6

10-2"

DL; Top slab = 258 psf

Walls = 132 "

Soil = 117

Base slab = 200

707 psf ↓

Uplift = $62.4 \times 10.17 = 635\ psf$ ↑

F.S. against floatation = $\frac{707}{635} = 1.11$

Try 2'-0" wide Ledge

$(29.5 + 2 \times 17.5) \times 2 \times 9.17 \times \frac{60}{1000} = \frac{71^k}{25.5 \times 17.5} = 159$

$\Sigma DL = 749\ psf$ F.S. $= 749/635 = 1.18 \approx 1.20$.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0100
SUBJECT: STD LIFT STATION - 4 PUMPS 500-2500 GPM EA			SHEET 4
DESIGNED: NMP	DATE: 2-10-95	CHECKED:	DATE:

VALVE PAD:

$A = 10'0\ (\pm)$ $\quad B/A = 2.00$
$B = 20'0$

Loads: 12" slab $= 150\ psf \times 1.4 = 210$
LL $= 300\ psf \times 1.7 = 510$
$w = 450\ psf$ $\quad 720\ psf$

$M_{Ad} = 0.072 \times 100 = 7.2\ ^{k}/ft$ $\quad \frac{qa^2}{1000} = \frac{0.720 \times 100}{1000} = 0.072$

$M_{Bw} = 0.072 \times 38 = 2.7\ ^{k}/ft$ $\quad d = 12 - 3 - \frac{1}{2} = 8.5''$

$K_{nA} = 100.$ $\quad \rho_{min} = 0.0033.$ $\quad F = 0.072$

$A_s = 0.34\ in^2/ft$ $\quad$ #5 @ 8" T & B E.W.

$V_{A_{max}} = 0.51 \times 450 \times 10 = 2.3\ ^{k}/ft$

$V_{ave} = \frac{2}{3} \times 2.3 = 1.53\ ^{k}/ft$ $\quad$ 8" wide G-wall

Soil $F_s = 2.3\ ksf < 3.00\ ksf$ allowable.

VALVE PIT No. 1 21'-2" X 25'-9" X 13'-0 walls t = 24".

Grating FRP wt = 25 psf
LIVE LOAD = 150
$\omega = 175$ psf.

SUPPORT BEAMS:

Beam B1.

$L_1 = 24'-5" - 2'-8" = 21'-9"$

$w = 175 \left(\frac{3.17 + 5.0}{2}\right) = 715$ plf
Bm. wt. = 35 "
$\omega = 750$ plf

$M = \frac{0.75 \times 21.75^2}{8} = 44.3^k$

$V = 0.75 \times 21.75/2 = 8.2\ k = R$

$W = 0.75 \times 21.75 = 16.3^k$

$\Delta = \frac{1.19 \times 16.3}{25} = 0.78" = \frac{L}{336}$

Use. W10X33 $l_u = 21.75$ $M_R = 47.5^{1k}$
w/ 2-3/4"φ Bolt connection.
3/8" PL w/ 5/16 weld
R = 8.2k

Beam B2

$L_2 = 21'-9"$

$w = \frac{175}{2}(5.0 + 5.5) = 918$ plf.
Bm. wt = 32
$w = 950$ psf

$M = \frac{0.95 \times 21.75^2}{8} = 56.2^{1k}$

$V = 0.95 \times 21.75/2 = 10.33\ k < R = 16.3^k$

$W = 20.66^k$

Use. W12X40 $l_u = 21.75'$ $M_R = 68.8^{1k}$
w/ 3-3/4"φ Bolts
3/8" PL, 5/16" weld
R = 16.3k.

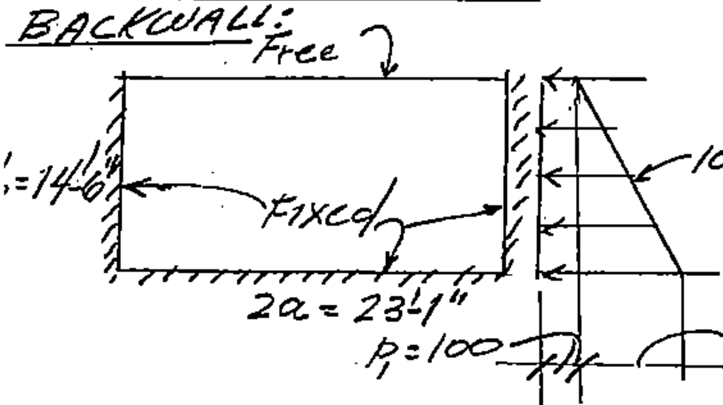
$\Delta = \frac{0.99}{37} \times 20.66 = 0.55" = \frac{L}{472}$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: HOUSTON, TX, STDS			JOB NO. 3921-00 010
SUBJECT: 3 WET & 2 DRY WEATHER Pumps SECURED SITE			SHEET 2 OF 9
DESIGNED: NMP	DATE: 12-4-95 5-3-95	CHECKED	DATE

VALVE PIT WALLS: 20'-6" X 24'-5 X 13'-0" walls, 24" Thickness

BACKWALL:



$a/b = 23.08/2 \times 14.5 = 0.79$

$p_1 b = 1.5$

$p_1 b^2 = 21.0$

$p_2 b = 21.0$

$p_2 b^2 = 305.0$

$M_x^- = 0.1788 \times 21 + 0.0433 \times 305 = 17.0$ k/ft, $M_{ux}^- = 28.8$ k/ft

$M_x^+ = 0.0807 \times 21 + 0.0214 \times 305 = 8.2 \qquad = 14.0$

$M_y^- = 0.1212 \times 21 + 0.0584 \times 305 = 20.4 \qquad = 34.6$

$M_y^+ = 0.0242 \times 21 + 0.0139 \times 305 = 4.7 \qquad = 8.1$

$t = 24''$ $\quad d_H = 20.0''$ $\quad F_H = 0.40$

$\qquad d_V = 21.0''$ $\quad F_V = 0.44$

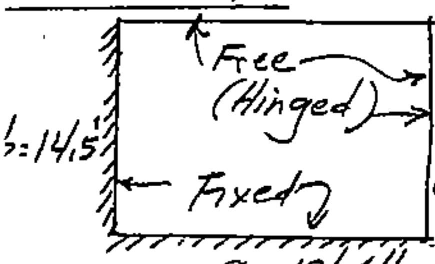
$K_{nH}^- = 72.$ $\quad \rho_H^- = 0.0013 \times 1\frac{1}{3} = 0.0017$, $A_s^- = 0.40 in^2/ft$ $\quad$ #6@14 HOF. at Corner,

$K_{nH}^+ = 35.$ $\quad \rho_H^+ = 0.0013 \times 1\frac{1}{3} = 0.0017$ $A_s^+ = 0.40 in^2/ft$ $\quad$ #6@14 HEF.

$K_{nV}^- = 79.$ $\quad \rho_V^- = 0.0015 \times 1\frac{1}{3} = 0.0020$ $A_s^- = 0.50 in^2/ft$ $\quad$ #6@7" DWL O.F.

$K_{nV}^+ = 18$ $\quad \rho_V^+ = 0.0013 \times 1\frac{1}{3} = 0.0017.$ $A_s = 0.40 in^2/ft$ $\quad$ #6@14 VEF.

SIDE WALL: $\quad a/b = 19.33/14.5 = 1.33 \simeq 1.00$ -



$M_x^- = 0.2949 \times 21 + 0.0662 \times 305 = 26.4$ k/ft, $M_u = 44.8$

$M_x^+ = 0.0324 \times 21 + 0.0077 \times 305 = 3.0 \qquad = 5.1$

(*) $M_y^- = 0.2949 \times 21 + 0.1157 \times 305 = 41.5^k \qquad = 70.5$

$M_y^+ = 0.0324 \times 21 + 0.0172 \times 305 = 5.9 \qquad = 10.0$

$t = 24''$ $\quad d_H = 20.0''$ $\quad F_V = 0.40$

$\qquad d_V = 21.0''$ $\quad F_H = 0.44$

$K_{nx}^- = 112.$ $\quad \rho_H^- = 0.0021 \times 1\frac{1}{3}$ $\quad A_{sx}^- = 0.67 in^2$ $\quad$ #6@7" HOF @ Corners

$K_{nx}^+ = 25$ $\quad \rho_H = \rho_V = 0.0013 \times 1\frac{1}{3}$ $\quad A_s = 0.40 in^2$ $\quad$ #6@14 EF EW

$K_{ny}^- = 160$ $\quad \rho_V^- = 0.0030 \times 1\frac{1}{3}$ $\quad A_{sy}^- = 0.72 in^2$ $\quad$ #6@7" VOF d/w/s. (*)

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, Tx STDS		JOB NO. 3921-00 01N
	SUBJECT: 3 WET & 2DRY WEATHER PUMPS		SHEET 3 OF 9
	DESIGNED: NMP	DATE 12-6-95 4-30-96 CHECKED	DATE

(*) Consider Vertical Edges hinged = $a/b = \frac{19.33}{2 \times 14.5} = 0.67 \approx 0.75$

$M_{y_{max}}^- = 0.2135 \times 21 + 0.0871 \times 305 = 31^{k/ft}$ $M_{uy} = 52.8^{k/ft}$

$K_{ny_{max}} = 120$ $\rho = 0.0023 \times 1/3$ $A_{s_{y_{max}}} = 0.73 in^2$. #6 @ 7" V.O.F. dwls.

Base slab: Consider Structure right of Exp. Joint:

Deadloads; 24" walls: $2 \times 20.67 \times 13.0 \times 2 \times 0.150 = 161.2^k$
$1 \times 21.75 \times 13.0 \times 2 \times 0.150 = 84.8$

2'-6" Base slab: $24.67 \times 33.75 \times 2.5 \times 0.150 = 312.2$
$W_c = 558.2^k$

Consider 4'-0" footing projection

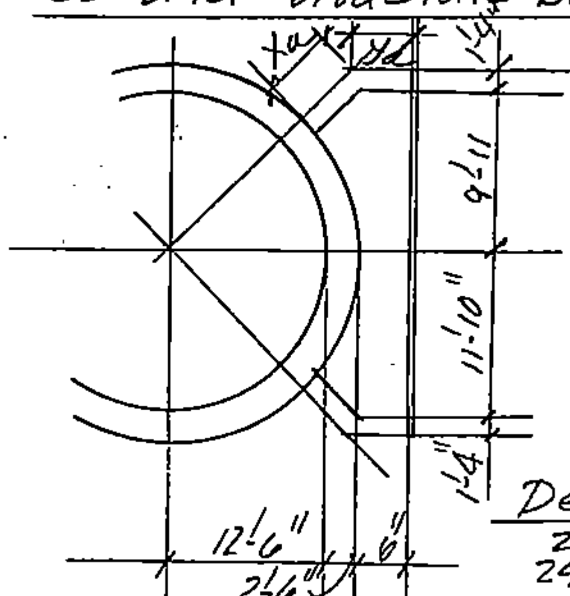
soil wt. $2 \times 24.67 \times 12.5 \times 4.0 \times 0.120 = 296.0k$
$1 \times 25.75 \times 12.5 \times 4.0 \times 0.120 = 154.5$
450.5

Uplift: $24.67 \times 33.75 \times 15.5 \times 0.062 = 800.1\,k$

$\frac{558.2}{1.10} + \frac{450.5}{1.50} = 507.5 + 300.3 = 807.8^k > F_u = 800.1^k$

$\frac{\Sigma W}{F_u} = \frac{1008.7}{800.1} = 1.26$ ok

Consider structure between Exp. Jt and Wet Well:



$X_a = \frac{(11.92 + 13.83)}{2 \times 0.707} - 15.0 = 3.22'$

$Y_a = 15.5 - 12.88 = 2.62'$

ave. Wall l = 5.84 ft

Top slab area = $2.62 \times 25.75 = 67.5$
$12.87 \times 12.88 = 165.8$
$-\pi \times 15^2/4 = -176.7$
$56.6\,ft^2$

Base slab area: $56.6 + 2 \times 5.84 \times 4 = 103.3\,ft^2$

Deadloads:

24" Top slab: $56.6 \times 2 \times 0.150 = 17.0^k$
24" Walls: $2 \times 11 \times 5.84 \times 2 \times 0.150 = 19.3^k$
30" Base slab: $103.3 \times 2.5 \times 0.150 = 38.7$
$W_c = 75.0k$

soil: $2 \times 5.84 \times 4 \times 12.5 \times 0.120 =$ $W_s = 70.1k$

Uplift = $103.3 \times 15.5 \times 0.062 = 99.3\,k$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX · STDS	JOB NO. 3921-00 0101
	SUBJECT: 3 Wet & 2 Dry weather Pumps	SHEET 4 OF 9
	DESIGNED: HMP DATE: 12-6-95 4-30-96 CHECKED	DATE

$$\frac{\Sigma W_c}{1.10} + \frac{\Sigma W_s}{1.50} = \frac{(558.2+75.0)}{1.10} + \frac{(450.5+70.1)}{1.50}$$

$$= 575.6 + 347.1$$

$$= \underline{922.7^k} > \Sigma F_u = 800.1 + 99.3 = \underline{899.4^k}$$

$$\frac{\Sigma W}{\Sigma F_u} = \frac{1153.8}{899.4} = \underline{1.28}$$

II Shear capacity of Dwl-bars in Base slab: @12" c/c.

$\phi V_c = 25.85^k$

OR $\phi V_c = \phi V_c' C_w C_t C_c$

$\phi V_c' = 24.52^k$ $\quad d_e = 11''$

$c_w = 1.0 \quad n_s = 1$

$c_t = 1.0 \quad h \gg 1.3 d_e = 14.3''$

$c_c = 1.0 \quad d_c > d_e$

$\phi V_c = \underline{24.52^k}$ (control) $> V_u = 8.43^k$

$\phi V_s = 27.1^k$

$M_u = 8.43 \times 0.50 = 4.21''^k$

$f_{s_t} = 42.93$ ksi

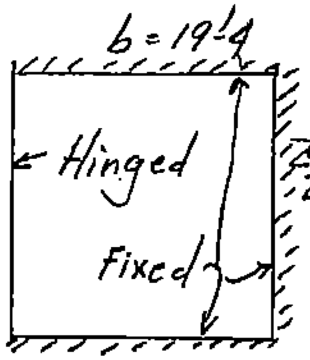
$f_{s_V} = \frac{8.43}{27.1} \times 60 = 18.66$ ksi

$f_s = \sqrt{42.93^2 + 18.66^2} = \underline{46.81 \text{ ksi} < F_s = 60 \text{ ksi}}$.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: HOUSTON, TX. STDS			JOB NO: 3921.00-0101
SUBJECT: 3 WET & 2 DRY WEATHER Pumps			SHEET: 5 OF 9
DESIGNED: NMP	DATE: 12-6-95 5-3-96	CHECKED:	DATE:

Base slab:



$a/b = \frac{23.08}{2 \times 19.33} = 0.60 \left\langle \begin{matrix} 0.50 \\ 0.75 \end{matrix} \right. \; 0.625$

Net uplift $= 0.062 \times 15.5 = 0.961$
$- 0.150 \times 2.5 = 0.375$
$0.586\ ksf \uparrow$

$pb = 11.33$
$pb^2 = 219.$

$M_x^- = 0.0695 \times 219. = 15.2^{1k}$, $M_{ux} = 25.8^{1k}$
$M_x^+ = 0.0274 \times 219. = 6.0$ $= 10.2$
$M_y^- = 0.0898 \times 219. = 19.7$ $= 33.5$
$M_y^+ = 0.0473 \times 219. = 10.4$ $= 17.7^{1k}$

$V_{Hinge\,(max)} = 0.3874 \times 11.33 = 4.39\ k/ft$ $V_u = 7.46\ k/ft$

$t = 30''$ $d_{min} = 28 - 3 - 2 = 23.0''$ $F = 0.529$
$\rho_{min} = 0.0018$ $A_{s\,min} = 0.50\ in^2.$

$\left.\begin{matrix} K_{mx}^- = 49. \\ K_{my}^- = 63. \\ K_{nx}^+ = 19. \\ K_{my}^+ = 33. \end{matrix}\right\}$ $\rho_{min} = 0.0018$ $A_s = 0.50 \left\langle \begin{matrix} 0.45 in^2\ \#6 @ 12\ T\&B\ EW \\ 0.55 in^2\ \#6 @ 7B\ \text{at walls.} \end{matrix} \right.$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT Houston, TX, STDS LP-SSC Pump STN-G2			JOB NO. 3921-00 0101
SUBJECT 3 Wet + 2 Dry Weather Pumps			SHEET 6 OF 9
DESIGNED NMP	DATE 12-11-95	CHECKED	DATE

VALVE PIT NO.2: 14'-0 X 18'-10 X 8'-8 Walls 1'-0" thick

Grating FRP Wt. = 25 psf
Live Load = 150 psf
w = 175 psf

Support beam:

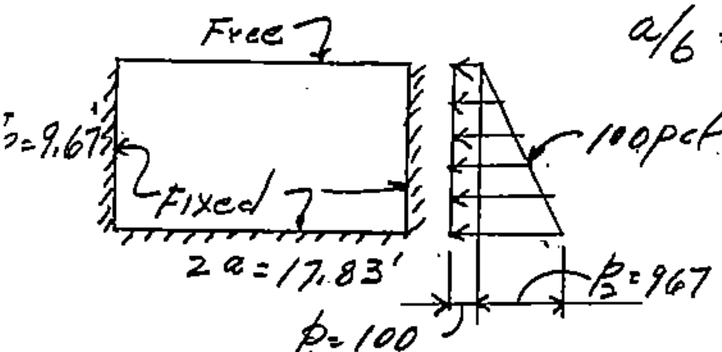
$w = 175\left(\frac{4.33+2.25}{2}\right) = 575$ plf
Bm wt = 25
600 plf.

$l = 16'\text{-}10''$
$M = 0.6 \times 16.83^2/8 = 21.2^{1k}$
$V = 0.6 \times 8.42 = 5.05^k$
$W = 10.1^k$

W8X24 $l_n = 16.83'$
$M_R = 33.5^{1k}$
2/5e W/2-3/4"φ Single 3/8" ℞ Conn. W/5/16 weld
R = 8.2k

$\Delta = \frac{0.89 \times 10.1}{19} = 0.47'' = \frac{1}{426}$

End Wall: Ref: 2/5 Bureau of Reclamation, EM No.27.



$a/b = \frac{17.83}{2 \times 9.67} = 0.92 \simeq 1.00$

$p_1 b = 1.0$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4.$

$M_x^- = 0.2613 \times 9.4 + 0.0644 \times 90.4 = 8.3^{1k/ft}$ $Mu = 14.1^{1k/ft}$
$M_x^+ = 0.1008 \times 9.4 + 0.0276 \times 90.4 = 3.4$ $= 5.9^{k/ft}$
$M_y^- = 0.2043 \times 9.4 + 0.0845 \times 90.4 = 9.6$ $= 16.3$
$M_y^+ = 0.0243 \times 9.4 + 0.0159 \times 90.4 = 1.7$ $= 2.8$

$t = 12''$ $d_{V_y} = 9.5''$ $F_V = 0.09$
$d_{H_x} = 8.5''$ $F_H = 0.07$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT Houston Tx STDS LP, SSC Pump Stn.			JOB NO. 3921-00 0101
SUBJECT Wet + 2 Dry weather Pumps			SHEET 7 of 9
DESIGNED NMP	DATE 12-14-95	CHECKED	DATE

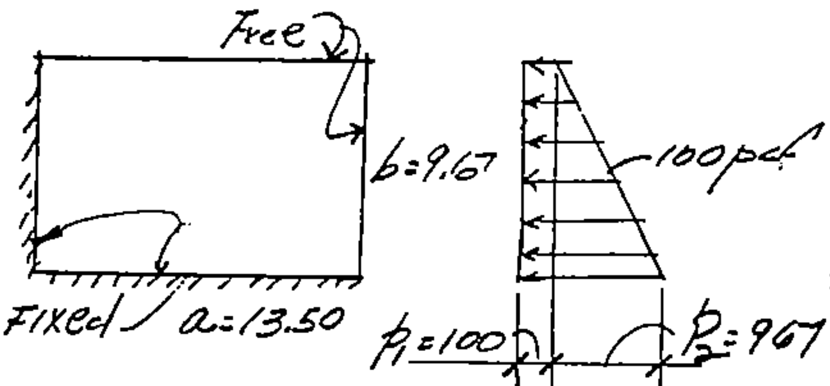
$K_{mx}^- = 201.$ $\rho = 0.0039$ $A_s^- = 0.0039 \times 12'' \times 8.5'' = 0.40 in^2/ft$ #5@6 H

$K_{mx}^+ = 84.$ $\rho_{min} = 0.0018$ $A_s = 0.0018 \times 12 \times 12 = 0.26$ #5@12 H IF

$K_{my}^- = 181.$ $\rho = 0.0035$ $A_s = 0.0035 \times 12 \times 9.5 = 0.40$ #5@6 DWL

$K_{my}^+ = 31.$ $\rho_{min} = 0.0018$ $= 0.26$ #5@12 VEF

Pit Side walls: $a/b = 13.5/9.67 = 1.4 \approx 1.00$.



$p_1 b = 1.0$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4$

$M_x^- = 0.2949 \times 9.4 + 0.0662 \times 90.4 = 8.8^{k}/ft$ $M_u = 14.9^{k}/ft$

$M_x^+ = 0.0324 \times 9.4 + 0.0077 \times 90.4 = 1.0$ $= 1.7^{k}/ft$

$M_y^- = 0.2949 \times 9.4 + 0.1157 \times 90.4 = 13.2$ $= 22.5$

$M_y^+ = 0.0324 \times 9.4 + 0.0172 \times 90.4 = 1.9$ $= 3.2$

$K_{nx}^- = 213.$ $\rho = 0.0041$ $A_{sx}^- = 0.42 in^2$ #5@6 @ Corner

$K_{nx}^+ = 24.$ $\rho_{min} = 0.0018$ $A_s = 0.26 in^2/ft$ #5@12 HEF.

$K_{ny}^- = 250$ $\rho = 0.0049$ $A_{sy}^- = 0.56 in^2/ft$ #5@6 dwls OF.

$K_{ny}^+ = 36.$ $\rho_{min} = 0.0018$ $A_s = 0.26 in^2/ft$ #5@12 VEF.

Buoyancy check: Consider Structure, Left of Exp. Jt.:

Dead Loads: Walls: $2 \times 14 \times 8.67 \times 0.150 = 36.4^k$

$1 \times 16.83 \times 8.67 \times 0.150 = 21.9$

3'-0" Ftg; 24" Base slab: $17.0 \times 24.83' \times 2' \times 0.150 = 126.6^k$

$W_c = 184.9k$

Soil: $2 \times 3.0 \times 8.17 \times 17.0' \times 0.120 = 100.$

$1 \times 3.0 \times 8.17 \times 16.83 \times 0.120 = 49.5$

$W_s = 149.5^k$

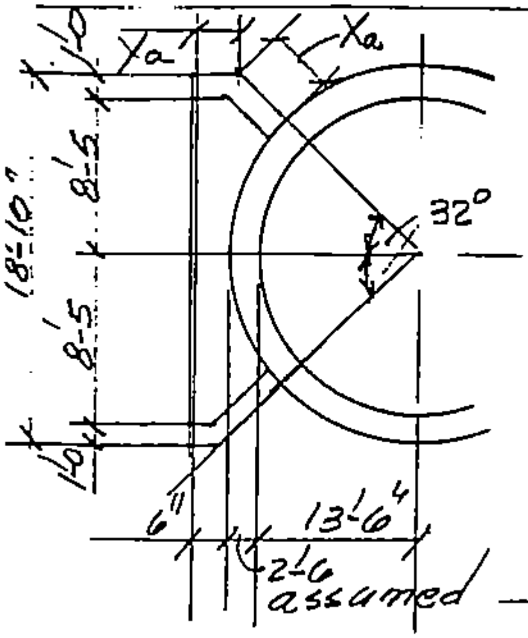
Uplift $= 17.0 \times 24.83' \times 10.67' \times 0.062 = 279.2^k = F_u$

$W_c/1.10 + W_s/1.50 = 267.8 < F_u$ $\Delta W = -11.4^k$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: Houston, Tx STDS			JOB NO. 3921.00 0101
SUBJECT: wet + 2 Dry weather pumps			SHEET 8 OF 9
DESIGNED: NMP	DATE: 5-1-96	CHECKED	DATE

Consider structure between Exp. Jt and Wet Well:



$Ya = 15.50 - 14.0 = 1.50'$

$Xa = \frac{9.42}{0.53} - 16.0 = 1.78$

Wall ℓ = 3.28' (approx).

Top slab arc: $1.50 \times 18.42 = 27.6$

$2 \times \frac{1}{2} \times 9.42 \times 15.0 = 141.3$

$- \pi \times 16^2 \times \frac{64}{360} = -142.9$

$= 26.0\ ft^2$

Base slab area $= 26.0 + 2 \times 3.28 \times 3.0$

$= 45.7\ ft^2$ approx.

assumed Dead loads:

24" Top slab $= 26 \times 2 \times 0.150 = 7.8^k$

12" walls : $2 \times 3.28 \times 6.67 \times 0.150 = 6.6$

24" Base slab: $45.7 \times 2 \times 0.150 = 13.7$

$W_c = 28.1^k$

Soil wt: $2 \times 3.0 \times 8.17 \times 3.28 \times 0.120 = 24.1^k$

Uplift : $45.7 \times 10.67 \times 0.062 = 30.2^k$

$\frac{\Sigma W_c}{1.10} + \frac{\Sigma W_s}{1.50} = \frac{213}{1.10} + \frac{173.6}{1.5} = 309.4^k = \Sigma F_u = 309.4^k$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS LP, 55C Pump Stn HZ	JOB NO: 3921-00 0101
	SUBJECT: 3Wet + 2 Dry weather Pumps	SHEET: 9 of 9
	DESIGNED: NMP · DATE: 12-14-95, 5-3-96 · CHECKED:	DATE:

Consider Combined bending and shear of dowels:

$M_u = V_u \times a = 0.50'' \times 7.37 = 3.69^{''k}$

$f_{s_t} = \dfrac{3.69}{0.7854 \times 0.5^3} = 37.59$ ksi

$f_{s_v} = \dfrac{7.37 \times 60}{27.1} = 16.32$ ksi

$f_s = \sqrt{37.59^2 + 16.32^2} = \underline{40.98 \text{ ksi}} < 60$ ksi.

II <u>Shear Capacity of 1"φ × 2'-0 dwl in base slab: @12" c/c.</u>

$\phi V_c = 25.85^k/\text{dwl}.$

or $\phi V_c = \phi V_c' C_w C_t C_c$ where $\phi V_c' = 15.2^k$ $d_e = 8''$

$C_w = 1,\ n_s = 1.$

$C_t = 1.\ \ h > 1.3 d_e = 10.4''$

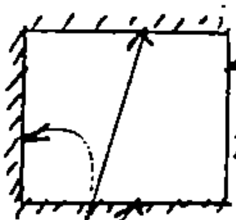
$C_c = 1,\ \ d_c > d_e$

$\underline{\phi V_c = 15.2^k/\text{dwl.}}$ controls $\gg V_u = 4.66^k/\text{ft or dwl.}$

$\phi V_s = 27.1^k/\text{dwl.}$

<u>Base Slab:</u>

$a/b = \dfrac{17.83}{2 \times 13.5} = 0.66$



Hinged

$2a = 17.83'$

Fixed $b = 13.5'$

Net Uplift $= 10 \times 62.4 = 624$
$\quad -1.33 \times 150 = -200$ psf
$\quad\quad 524$ psf ↑

$pb = 7.07$

$pb^2 = 95.5$

$t = 24''$ $d = 22 - 3 - \frac{1}{2} = 18.5''$ $F = 0.342$

$M_x^- = 0.0695 \times 95.5 = 6.64$ $M_u = 11.3^k/\text{ft}$ $K_n = 33.$

$M_x^+ = 0.0274 \times 95.5 = 2.62$ $= 4.4$ $= 13.$

$M_y^- = 0.0898 \times 95.5 = 8.58$ $= 14.6$ $= 43$

$M_y^+ = 0.0473 \times 95.5 = 4.52$ $= 7.7$ $= 23$

$\rho_{min} = 0.0018$

$A_{s\,min} = 0.40\text{ in}^2$

$V_{hinge\,max} = 0.3874 \times 7.07 = 2.74^k/\text{ft}$ $V_u = 4.66^k/\text{ft}$ or

#6 @ 12" TEW

#5 @ 8 TEW

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	CITY OF HOUSTON PROJECT			3904-00 JOB NO. 0101
	LIFT STN W/O VALVE VAULT SUBJECT 3 WET & 2 DRY WR. PUMPS			12 SHEET
	NMP DESIGNED	11-1-94 DATE	JAM CHECKED	11-7-94 DATE

(sht. C31)

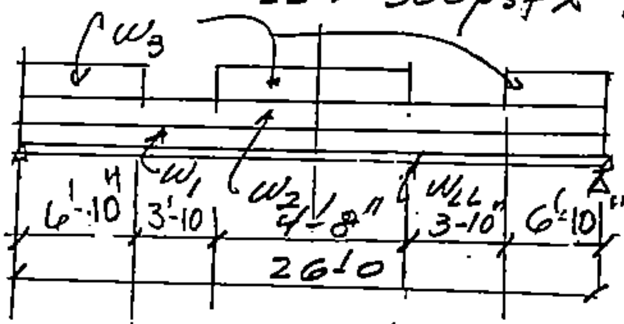
WET WELL: TOP SLAB:

Consider 24" thick slab:

Band 1: $b = 3'\text{-}0\tfrac{3}{4}" \; 0\text{-}9\tfrac{1}{4}" \} = 3'\text{-}10"$

w = DL: $w_1 = 300 psf \times 3.83' = 1150$ plf
$w_2 = 30 psf \times 4.75' = 143$
$w_3 = 300 \times 2.25' = 675$ } w_{DL}

LL: $300 psf \times 8.58' = 2574 = w_{LL}$



LL $33.5 \times 1.7 = 57.0^k$ — 33.5^k

$w_1 + w_2$ 16.8, w_3 6.2 } $= 23^k \times 1.4 = 32.2^k$ — 16.8^k, 6.2 } $= 23^k$

$V_u = 89.2^k < \phi V_c$.

$\phi V_c = 0.85 \times 2\sqrt{4000} \times 46 \times 21 = 103.9^k$

$M_u = 90.2 \times 13' = 1173.$
$-57 \times 6.5' = -371,$
$-23.5 \times 6.5 = -153,$
$-6.45 \times 11.83 = -76.$
$-2.23 \times 1.17' = -3,$

$M_u = 570^{k}$

$d = 21"$ ($M_{u,des.} = 741^{k}$)

$F = 3.83 \times 0.441 = 1.689$

$K_n = 337.$ (439)

$\rho = 0.0067$ (0.0088)

$A_s = 6.47 in^2$ ($8.50 in^2$)

11 #8 Bott @ 4" c/c.

Band 2: $d = 21"$
$b = 2.62 = 31"$ $F = 1.14$

$l = 2\sqrt{12.5^2 - 5.83^2} + 1.0 = 23.12$ ft

$w_{DL} = 2.62' \times 300 psf = 0.79$
$30 psf \times 2.5 = 0.08$ } $0.87 \times 1.4 = 1.22^k/ft$

$w_{LL} = 300 psf \times 5.12' = 1.54 \times 1.7 = 2.61^k/ft$

$w_u = 3.83^k/ft$

$M_u = 3.83 \times 23.12^2/8 = 256^{k}$ (333)

$K_n = \cancel{226}$. (292) $\rho = 0.0044$ (0.0057) $V_u = 42.4$ $V_{u_d} = 35.7^k$

$\cancel{A_s} = 2.8 in^2$ (3.71) 4 #8 @ 8" c/c Bott. $\phi V_c = 35^k \approx V_{u_d}$.

[5 #8 @ 7" c/c Bott.]

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904-00-0101
SUBJECT: LIFT STN W/O VALVE VAULT 3 WET & 2 DRY PUMPS			SHEET 13
DESIGNED: NMP	DATE: 11-2-94	CHECKED: JAM	DATE: 11-7-94

Band 3: $l = \left.\begin{matrix} 4'-6\frac{1}{2} \\ 2'-0 \end{matrix}\right\} 6.55'$

$w = \left.\begin{matrix} DL = 300 \times 1.4 = 0.42 \\ LL = 300 \times 1.7 = 0.51 \end{matrix}\right\} = 0.93\ k/ft$

$M_u = 0.93 \times 6.55^2/8 = 5\ ^{k}/ft$

$d = 24 - 3 - 1 = 20\ in \quad F = 0.40$

$A_{s\,min} = 0.0033 \times 240 = 0.8\ in^2$
#8@12 Bott. Trans.

VALVE PADS:

$A = \left.\begin{matrix} 16-1 \\ -\ 1-0 \end{matrix}\right\} = 15'1'' \quad m = \frac{A}{B} = 0.82$

$B = \left.\begin{matrix} 19'-5 \\ -\ 1-0 \end{matrix}\right\} = 18'5''$

$W =$ 12" Slab = 150 psf × 1.4 = 210 psf
LL. (No Truck). = 150 psf × 1.7 = 255 psf
$w = 300$ psf $\quad W_u = 465$ psf

$M_{u_A} = 0.056 \times 0.465 \times 15.08^2 = 6\ ^{k}/ft \quad K_n = 94$

$M_{u_B} = 0.023 \times 0.465 \times 18.42^2 = 3.6\ ^{k}/ft$

$d_A = 12'' - 3'' - 1 = 8'' \quad F = 0.064 \quad \rho_{min} = 0.0033$

$d_B = 12 - 4 - 1 = 7'' \quad F = 0.049 \quad A_{s\,min} = 0.31\ in^2$

#5@12 Bott. EW.
#5@8 Top EW

$V_A = 0.465 \times \frac{0.71}{2} \times 15.08 = 2.49\ k/ft\ (max)$

Gr. Wall Loads: platform = 2.49/1.55 = 1.61 k/ft
12" wall 2.5 × 0.150 = 0.38
1.99 k/ft

Brg pressure: 1.99 ksf < 3.0 ksf allow.

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: City of Houston	JOB NO. 3904-02 0101
	SUBJECT: Lift Station w/ Vaults 3 Wet + 2 Dry Pumps.	SHEET 14
	DESIGNED: NMP / DATE: 1-18-95 / CHECKED:	DATE:

NOTE: Wetwell Top Slab Similar to Lift Stn. w/o Valve Vault.

VALVE VAULT

Top Slab: Assume 24" thick slab:

Loads: 24" slab = 300 psf

Hatch @ 30 x 2.5 = 75 " $\}$ x1.4 = 525

Larger Vault — LL: @ 300 psf = 300 " x1.7 = 510

$L = 21'9"$ — 675 psf — W_u 1035 psf

$M_u = 1.04 \times 21.75^2/8 = 61.5$ k/ft — $d = 21"$ $F = 0.441$

$V_u = 1.04\left(\frac{21.75}{2} - 1.75\right) = 9.5$ k/ft $< \phi V_c = 2\sqrt{4000} \times 12 \times 21 \times 0.85$ $= 27.1$ k/ft

$K_n = 139$ $\rho = 0.0027$ $\rho_{min} = 0.0033$

$A_{s\,min} = 0.83\,in^2$ OR #8 @ 12" Bottom (0.79) / #7 @ 8 Bott (0.90 in²/ft). #5 @ 8 Top EW and Bott transverse.

Smaller Vault

$l = 17'10"$

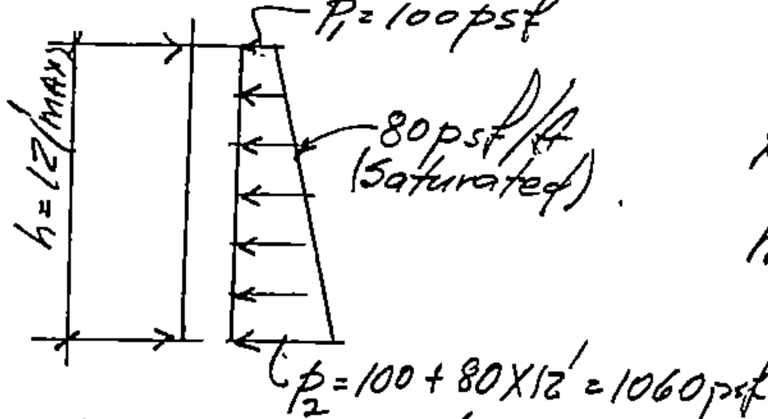
$M_u = 1.04 \times 17.83^2/8 = 41.3$ k/ft

$V_u = 1.04\left(\frac{17.83}{2} - 1.75\right) = 7.5$ k/ft $< \phi V_c = 27.1$ k/ft

Use $\rho_{min} = 0.0033$ $A_s = 0.83\,in^2$.

WALLS:

$h_{max} = 11'0, 12'0 \} = 12'0"$ $t = 12"$ $d = 12 - 2\frac{1}{2} - \frac{1}{2} = 9"$



$p_1/p_2 = \frac{100}{1060} = 0.10$ $F = 0.081$

$Q = \frac{(100 + 1060)}{2} \times 12' = 6.96$ k

$R_{Bot} = 0.65 \times 6.96 = 4.52$ k, $R_{Top} = 0.35 \times 6.96 = 2.44$ k/ft

$M_{max} = \frac{6.96 \times 12}{7.82} = 10.7$ k/ft

$M_u = 1.7 \times 10.7 = 18.2$ k/ft

$V_u = 1.7 \times 4.52 = 7.68$ k/ft $< \phi V_c$

$K_n = 225$ $\rho = 0.0043$ $A_s = 0.46\,in^2$ $\phi V_c = 0.85 \times 2\sqrt{4000} \times 9 \times 12 = 11.6$ k/ft

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT CITY OF HOUSTON			JOB NO. 39040001
	SUBJECT Lift Station w/Vaults 3 Wet + 2 Dry Pumps			SHEET 15
	DESIGNED NMP	DATE 1-18-95	CHECKED	DATE

BASE SLAB:

Loads : Top slab DL 300 psf

LL 300 psf

Walls 22.75'

20.50'

20.50'

$63.75 \times 11 \times 0.150 = 105.2^k$; $\frac{105.2}{20.5 \times 22.75} = 225$ psf

Consider Water Table to be up to Finished Grade

Des. Engr - Varify for 100 year flood level, if Critical.

$h_w = $ 1'-0", 11'-0, 1-6" } = 13-6" uplift = $62.4 \times 13.5 = 842$ psf

DL: 24" Top slab = 300

1'-0 walls = 225

1'-6" Base slab = 225

750 psf

Backfill wt on footing, say 1'-0 wide.

$65.75' \times 1' \times 12' \times 0.06 = 47.3^k$

$W_{eq} = \frac{47.3}{20.5 \times 22.75} = 100$ psf

$\Sigma W_{DL} = 850$ psf $\gg$ uplift = 842 psf.

Soil pressure = DL = 850

LL = 300

1150 psf $\ll$ 3000 psf min. allow. Soil bearing.

Des. Engr - Verify.

W = 300 Top slab $\times 1.4 = 420$

300 LL $\times 1.7 = 510$

225 walls $\times 1.4 = 315$

100 soil wt $\times 1.4 = 140$

W = 925 psf $W_u = 1385$ psf

t = 18" base slab

d = 18-2-1 = 15" F = 0.225

$M_u = 1.385 \times 21.75^2/8 = 81.9$ k/ft $K_n = 364$, $\rho = 0.0072$

$V_u = 1.385\left(\frac{21.75}{2} - 1.25\right) = 13.3$ k/ft $< \phi V_c = 0.85 \times 2\sqrt{4000} \times 12 \times 15$

$= 19.35$ k/ft

$A_s = 1.295$ in²/ft #8 @ 8" Top

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT CITY OF HOUSTON			390400 JOB NO. 0101
SUBJECT Lift Station w/Vaults 3 Wet + 2 dry Pumps			16 SHEET
NMP DESIGNED	1-18-95 DATE	CHECKED	DATE

Consider Base Slab as Two-way

$a \times b = 21.75'$ $m = 1.00$. Hinged all sides.

$m^+ = 0.036 \times 1.39 \times 21.75^2 = 23.7$ k/ft

$K_n = 105$ $\rho_{min} = 0.0033$: $A_s = 0.59$ in² -

#7@12 T.EW

#5@12 Bott. EW.

Assume F.S. against uplift = 1.20

Net uplift = $(1.2 \times 842 - 850) = 160$ psf.

a. Consider base slab to resist by Cantilever off the wetwell shaft

$M_u = 1.7 \times 0.160 \times 22.5^2/2 = 68.9$ k/ft

$F = 0.225$, $K_n = 306$ $\rho = 0.006$

$A_s = 1.08$ in² #8@8" dwls.

b. Consider net uplift shared by Top slab and base slab equally

$\therefore M_u = 34.5$ k/ft

$K_n = 153$ $\rho_{min} = 0.0033$ $A_s = 0.59$ in²/ft

#7@12 Bot. Dwls from Wet well wall.

✓ Use this

c. Increase wall thickness $t_w = 16"$, base slab - $t = 2'0"$ and Base slab projection 2'-0".

$h_w = \left.\begin{array}{l} 2'0 \\ 11\text{-}0 \\ 2\text{-}0 \end{array}\right\} = 15'$ uplift $= 62.4 \times 15 = 936$ psf ↑

DL: Top slab = 300 psf

Base slab = 300 "

walls = $\left.\begin{array}{l} 20.50 \\ 20.50 \\ 23.42 \end{array}\right\} = 64.42' \times 11 \times 1.33 \times 150 = \dfrac{141.4^k}{20.5 \times 23.42}$

$= 294$ psf.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF Houston | JOB NO 3904.00 0101
SUBJECT: Lift Station w/Vaults 3 wet + 2 dry Pumps | SHEET 17
DESIGNED: NMP | DATE 1-19-95 | CHECKED | DATE

Soil Wt:

$$\begin{array}{r} 20.50 \\ 20.50 \\ 27.42 \\ \hline 68.42 \end{array} \times 14. \times 2.0 \times 60 = \frac{115.^{k}}{20.50 \times 23.42} = 239 psf$$

ΣDL = Top slab = 300 psf
Base slab = 300
walls = 294
Soil = 239
$\overline{1133}$ psf ↓

$$F.S = \frac{1133}{936} = 1.21$$

Small Valve Vault:

h_w = 2'-0"
6'-8"
1'-6
$\overline{10'-2"}$

uplift = 10.17' × 62.4 = 635 psf ↑

DL : 24" Top slab = 300 psf
12" Walls

$$\begin{array}{r} 12.50 \\ 12.50 \\ 18.83 \\ \hline 43.83' \end{array} \times 6.67 \times 150 = \frac{43.85^{k}}{12.5 \times 18.83} = 186 psf$$

18" Base slab = 225 psf

ΣDL = 711 psf $F.S. = \frac{711}{635} = 1.12$

Assume 1'-0 Base Slab extension:

Wt of Soil:

$$\begin{array}{r} 12.50 \\ 12.50 \\ 12.50 \\ 20.83 \\ \hline 45.83 ft \end{array} \times 9.17' \times 1.0 \times 60 = \frac{25.2^{k}}{12.5 \times 18.83} = 107 psf$$

ΣDL = 818 psf $F.S. = \frac{818}{635} = 1.29 > 1.20.$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT City of Houston		JOB NO. 3904-00 0101
	SUBJECT Lift Station w/Vaults 3 wet + 2 dry Pumps		SHEET 18
	DESIGNED NMP	DATE 1-19-95	CHECKED	DATE

Base Slab

Loads: Top slab = 300 psf
Walls = 186 "
Soil = 107 "
$\} \times 1.4 = 830$

LL. Top slab = 300 psf $\times$ 1.7 = 510

w = 893 psf $\quad w_u$ = 1340 psf.

Consider Two-way slab, hinged all edges.

$A = 13'6"$
$B = 17'10"$ $\quad m = 0.76$

$M^+_{uA} = 0.061 \times 1.34 \times 13.5^2 = 14.9\ ^{k}/ft$ $\quad K_n = 88$

$M^+_{uB} = 0.019 \times 1.34 \times 17.83^2 = 8.1\ ^{k}/ft$

$d = 16 - 2 - 1 = 13"$ $\quad F = 0.169$

$\rho_{min} = 0.0033$ $\quad A_s = 0.51\ in^2.$ $\quad$ #5@8 T EW (0.47)

#5@12 Bott EW

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS LP, SSC, PUMP STN HZ	JOB NO. 3921-00 0101
	SUBJECT: 4 WET & 2 DRY WEATHER PUMPS	SHEET 1 OF 9
	DESIGNED: NMP · DATE: 12-7-95 · CHECKED:	DATE:

VALVE PIT No. 1: 21'-2" X 30'-9" X 13'-0 walls $t = 24''$

Grating FRP wt. = 25 psf
Live Load = 150 psf
w = 175 psf

Support Beams:

Beam B1: $l = 29'5'' - 2\text{-}8 = 26'9''$

$w = 175\left(\frac{3.17 + 5.0}{2}\right) = 715$ plf
Bm wt = 35
750 plf

$M = 0.75 \times 26.75^2/8 = 67.0^k$
$V = 10.0^k$
$W = 20.0^k$

W12X35 $l_u = 14' \pm$
$M_R = 75^{k}$
3-3/4"φ single-PL shear connection
$R = 16.3^k > V = 10^k$

$$\Delta = \frac{5 \times 20 (26.75 \times 12)^3}{384 \times 29 \times 10^3 \times 285} = 1.04'' = \frac{l}{308}$$

$b_f = 6\tfrac{1}{2}''$
30
$36\tfrac{1}{2} \rightarrow 38''$

Beam B2: $l = 26'9''$

$w = 175 \times \left(\frac{5.0 + 5.5}{2}\right) = 920$ plf
Bm. wt = 40
960 plf

$M = 0.96 \times 26.75^2/8 = 85.9^{k}$
$V = 0.96 \times 26.75/2 = 12.84^k$
$W = 25.68^k$

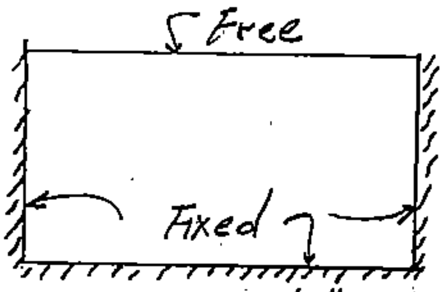
W12X40 $l = 14 \pm$
$M_R = 95^{k}$
3-3/4"φ single PL shear Conn.
$R = 16.3^k > V = 12.84^k$

$$\Delta = \frac{5 \times 25.68 (26.75 \times 12)^3}{384 \times 29 \times 10^3 \times 310} = 1.23'' = \frac{l}{261} < \frac{l}{240}$$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	HOUSTON, TX STDS PROJECT		3921-00 JOB NO. 0101
	4 WET & 2 DRY WEATH. PUMPS SUBJECT		2 OF 9 SHEET
	NMP DESIGNED	12-7-95 DATE 5-3-96	CHECKED	DATE

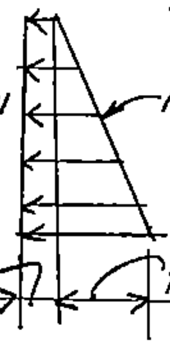
VALUE PIT WALLS:

$a/b = \frac{25.08}{2 \times 14.5} = 0.86 <$ 0.75 / 0.88 / 1.00



$b = 14'6''$

$2a = 25'1''$



$p_1 = 100$ $\quad p_2 = 1450$ psf

$p_1 b = 1.5$
$p_1 b^2 = 21.0$
$p_2 b = 21.0$
$p_2 b^2 = 305.0$

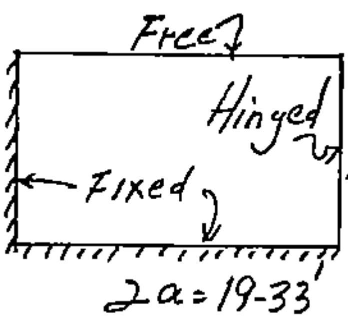
$M_x^- = 0.2205 \times 21 + 0.0525 \times 305 = 20.6$ ${}^{1k}/_{ft}$; $M_{ux}^- = 35.1$ ${}^{1k}/_{ft}$
$M_x^+ = 0.0908 \times 21 + 0.0245 \times 305 = 9.4$ $\quad = 16.0$
$M_y^- = 0.1628 \times 21 + 0.0715 \times 305 = 25.2$ $\quad = 42.9$
$M_y^+ = 0.0242 \times 21 + 0.0149 \times 305 = 5.1$ $\quad = 8.6$ ${}^{1k}/_{ft}$

$t = 24''$ $\quad d_H = 20.0''$ $\quad F_H = 0.40$
$\quad d_V = 21.0''$ $\quad F_V = 0.44$

$K_{nx}^- = 88.$ $\quad \rho = 0.0016 \times 1\frac{1}{3} = 0.0021$ $\quad A_{sH}^- = 0.50 in^2$ $\quad$ Hori. @ Corn. #6 @ 7"
$K_{nx}^+ = 40.$ $\quad \rho = 0.0013 \times 1\frac{1}{3} = 0.0017$ $\quad A_{sH}^+ = 0.40$ $\quad$ 6@14 HEF
$K_{ny}^- = 98.$ $\quad \rho = 0.0018 \times 1\frac{1}{3} = 0.0024$ $\quad A_{sV}^- = 0.60$ $\quad$ #6@7" VOF DWLS.
$K_{ny}^+ = 20.$ $\quad \rho = 0.0013 \times 1.33 = 0.0017$ $\quad A_{sV} = 0.42 in^2$ $\quad$ #6@14 VEF

$V_{y\,max} = 0.7588 \times 1.5 + 0.4320 \times 21. = 10.2$ k/ft
$V_y = 10.2 - 1.5 \times 1.13 = 8.51$ k/ft $\quad V_u = 14.47$ k/ft
$\phi V_c = 2 \times 0.85 \sqrt{4000} \times 12 \times 21.0''$
$= 27.10$ k/ft $> V_{u\,max} = 14.47$ k/ft.

SIDE WALLS:



$2a = 19{-}33'$

Consider hinged Vertical Edges.

$a/b = \frac{19.33}{2 \times 14.5} = 0.67 \approx 0.75$

$b = 14.5'$ $\quad M_x^+ = 0.1217 \times 21 + .0337 \times 305 = 12.8$ ^{1k} $\quad M_{ux}^+ = 21.8$ ${}^{1k}/_{ft}$
$M_y^- = 0.2136 \times 21 + 0.0871 \times 305 = 31.05$ $\quad = 52.8$
$M_y^+ = 0.0304 \times 21 + 0.0168 \times 305 = 5.8$ $\quad = 9.8$

$K_{nx}^- = 55$ $\quad \rho = 0.0013 \times 1.33 = 0.0017$ $\quad A_{sH}^- = 0.40$ #6@14
$K_{ny}^- = 120$ $\quad \rho = 0.0023 \times 1.33 = 0.0030$ $\quad A_{sV}^- = 0.76$ #6@7"
$K_{ny}^+ = 22$ $\quad \rho = 0.0013 \times 1.33 = 0.0017$ $\quad A_{sV}^+ = 0.42$ #6@14

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: HOUSTON, TX, STDS			JOB NO.: 3921
SUBJECT: 4 WET & 2 DRY WEATHER PUMPS			SHEET: 3 OF 9
DESIGNED: NMP	DATE: 12-8-95	CHECKED:	DATE:

Buoyancy Check: Consider Structure right of Exp. Jt.

DEAD LOADS: 24" Walls: $2 \times 20.66 \times 13 \times 2 \times 0.150 = 161.2^k$

$1 \times 26.75 \times 13 \times 2 \times 0.150 = 104.3$

2'-6" Base slab: $24.67 \times 38.75 \times 2.5 \times 0.150 = 358.5^k$

$W_c = 624.^k$

4.0 Ftg soil wt: $2 \times 24.67 \times 12.5 \times 4 \times 0.120 = 296.0$

$1 \times 30.75 \times 12.5 \times 4 \times 0.120 = 184.5$

$W_s = 480.5^k$ $\quad \Sigma W = 1104.5^k$

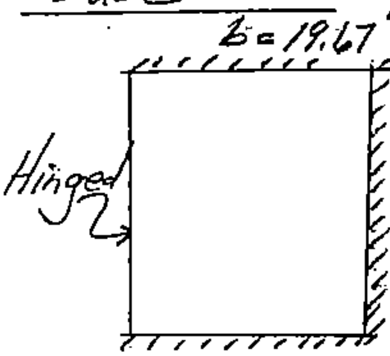
Uplift $= 24.67 \times 38.75 \times 15.5 \times 0.062 = F_u = 918.7^k$ $\quad F.S. = \dfrac{1104.5}{918.7} = 1.20$

$\dfrac{624}{1.10} + \dfrac{480.5}{1.50} = 567.3 + 320.3 = 887.6^k < F_u$

$\Delta W = -33.1^k$

NOTE: See sht. 69a for additional calculations for Bouyancy check.

Base slab:



Net uplift $= 0.062 \times 15.5' = 0.967 \uparrow$
$-2.50 \times 0.150 = 0.375 \downarrow$
$p = 0.592 \uparrow$ ksf.

$pb = 11.6$

$pb^2 = 229.$

$a/b = \dfrac{28.75}{2 \times 19.67} = 0.73 \approx 0.75$

$M_x^- = 0.0695 \times 229 = 15.9$ 'k/ft $\quad M_{ux}^- = 27.0$ 'k/ft $\quad K_{mx}^- = 42.$

$M_x^+ = 0.0274 \times 229 = 6.3$ 'k/ft $\quad = 10.7$

$M_y^- = 0.0898 \times 229 = 20.6$ 'k/ft $\quad = 35.0$ $\quad K_{my}^- = 54$

$M_y^+ = 0.0473 \times 229 = 10.8$ 'k/ft $\quad M_{uy}^+ = 18.4$ 'k/ft

$t = 30''$ $\quad d_T = d_B = 30'' - 3'' - \frac{1}{2}'' - 1'' = 25.5''$ $\quad \phi = 0.650$

$\rho_{min} = 0.0018$ $\quad A_{s\,min} = 0.0018 \times 12 \times 30 = 0.65$ in²/ft

#6 @ 8" TEW

$V_{hinge\,max} = 0.3874 \times 11.4 = 4.42$ k/ft

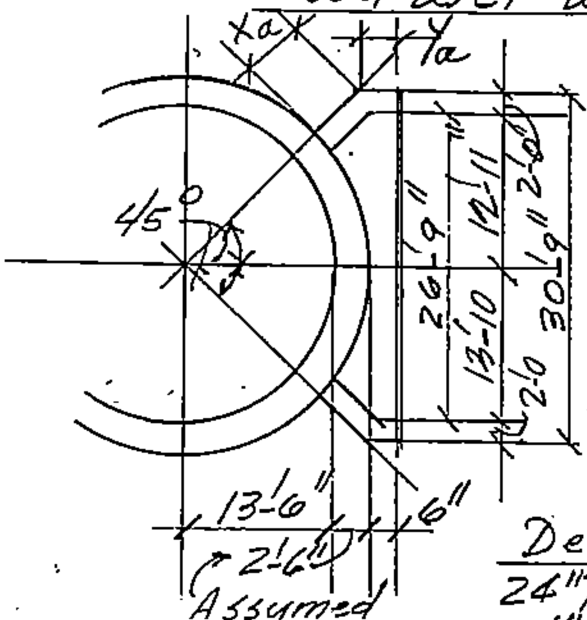
#6 @ 12 BEW w/ #6 @ 7" (Wall dwls)

$V_u = 7.50$ k/ft $< \phi V_c = 25.85^k$

CTE ENGINEERS — CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: Houston, Tx Stds		JOB NO. 3921-0101
	SUBJECT: 4 Wet + 2 Dry weather Pumps		SHEET 3a OF 10
	DESIGNED: NMP	DATE: 5-1-96	CHECKED	DATE

Buoyancy check: Cont.

Consider structure between Exp. Joint and Wet Well:



$X_a = \frac{30.75}{2 \times 0.707} - 16.0 = 4.02'$

$Y_a = 16.5 - 15.38 = 1.12'$

ave. wall l = 5.14 ft.

Top Slab area = 1.12 X 30.75 = 34.4
15.38 X 15.38 = 236.5
$-\pi \times 16.^2/4$ = -201.0
70.0 ft²

Base slab area: 70. + 2X5.14X4'
= 111.1 ft²

Deadloads

24" Top slab: 70 X 2 X 0.150 = 21.0 k
24" Walls: 2X5.14X11'X2X0.150 = 33.9
30" Base Slab: 111.1X2.5X0.150 = 41.7

W_c = 96.6 k

Soil wt: 2 X 4' X 5.14 X 12.5 X 0.120 = 61.7 k
Uplift: 111.1 X 15.5 X 0.062 = 106.8 k

$\frac{(624 + 96.6)}{1.10} + \frac{(480.5 + 61.7)}{1.50}$

655.0 + 361.5 = 1016.5 k < F_u = 1025.5

ΔW = -9.0 k.

ΣW_c = 720.6
ΣW_s = 542.2
ΣW = 1262.8 k
ΣF_u = 1025.5 k
FS = 1.23.

NOTE: 1. To Conform w/ COH Des. MNL floatation F.S. the Dead wt. is short by 9.0 kips. Insignificant.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS		JOB NO. 3921-00 0101
	SUBJECT: 4 Wet + 2 Dry Weather Pumps		SHEET 4 of 9
	DESIGNED: NMP	DATE: 12-8-95	CHECKED	DATE

REF: PCI, Design Hand Book: 4^{th} Ed. Table 6.20.8

NOTE: this Table can be used to evaluate Shear capacity of 1" DIA. dowel bar in Expansion joint TYPE-E3. 1" Dia at 12" o/c in walls and base Slab.

I Shear capacity in Wall:

$\phi V_c = 25.85^k$/Dowel For $\lambda = 1$, $f'_c = 4000$ psi $f_{sy} = 60{,}000$ psi, $d_b = \frac{7}{8}"\phi$ ($\frac{1}{8}"$ for Corrosion Loss.)

or $\phi V_c = \phi V'_c C_w C_t C_c$ where $\phi V'_c = 27.94^k$, for $d_e = 12"$

$= \underline{24.2^k}$ ← Controls

$C_w = 1.0$ $b = 0$

$\phi V_s = 27.1^k$

$C_t = 1.0$, $h >> 1.3 d_e$

$C_c = 0.87$ $d_c = 8"$

II Shear Capacity in Base Slab:

$\phi V_c = \underline{25.85^k}$ ← Controls

or $\phi V_c = \phi V'_c C_w C_t C_c$ where $\phi V'_c = 27.94^k$; $d_e = 14"$

$= 27.94^k$

$C_w = 1.$, $n_s = 1.$

$C_t = 1.0$ $h >> 1.3 d_e$

$\phi V_s = 27.1^k$

$C_c = 1.0$ $d_c > d_e$

Wall dowels: $1"\phi$ @ $12"$

$V_u = 11.24^k$

$M = 11.24 \times 0.5" = 5.62"^k$

$f_v = \frac{11.24}{27.1} \times 60 = 24.88$ ksi

.0982

$f_{st} = \frac{5.62}{0.7854 \times 0.5^3} = 57.24$ ksi

$f_s = \sqrt{57.24^2 + 24.88^2} = \underline{62.4 \text{ ksi}}$

Note: Walls will not get full uplift reaction. Base slab will take some.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston Tx, STDS			JOB NO 3921-00 0101
	SUBJECT 4 Wet + 2 Dryweather Pumps			SHEET 5 of 9
	DESIGNED NMP	DATE 12-8-95	CHECKED	DATE

Wall bracket from Wet Well: 9-3-96

Ref: PCA "Simplified Design" shear walls, pg 6-13.

$$\phi M_n = \phi\left[0.5 A_{st} f_y l_w \left(1+\frac{P_u}{A_{st}f_y}\right)\left(1-\frac{c}{l_w}\right)\right]$$

where $\phi = 0.90$

A_{st} = #6@12 HEF = $0.44 \times 2 \times 13 = 11.44$ in^2

$l_w = 13' = 156''$ $h = 24''$ wall thickness

$P_u = 0$ across joint

$$\omega = \frac{A_{st}}{l_w h}\frac{f_y}{f'_c} = \frac{11.44 \times 60}{156 \times 24 \times 4} = 0.046$$

$$\frac{c}{l_w} = \frac{\omega}{2\omega + 0.85\beta_1} \qquad \beta_1 = 0.85 \text{ for } f'_c = 4000$$

$$= \frac{0.046}{0.092 + 0.722} = 0.057$$

$$\phi M_n = \frac{0.90}{12}\left[0.5 \times 11.44 \times 60 \times 156\,(0.94)\right] = 3787^{\,\prime k}$$

Assume wet well wall 2'-0 thick (min).

$R_o = 13.5 + 2. = 15.50'$

l = Cantilever = $\sqrt{15.5^2 + 15.17^2} - 15.50 = 6.19'$

$M_u = 1.7 \times 86 \times 6.19 = 905^{\,\prime k} \ll 3787^{\,\prime k}$

Base slab bracket from Wetwell wall:

$l_{max} = 6.19 \cos 45° = 4.38'$

$M_{u\,max} = 7.5 \times 4.38 = 32.8$ 'k/ft $\qquad$ $t = 2'\text{-}4'' = 28''$

$K_n = 8.2$

$\rho_{min} = 0.0018$ $\qquad$ $d = 20''$ $F = 0.400$

$A_s = 0.0018 \times 20 \times 12 = 0.43$ in^2/ft $\qquad$ #6@12" provided.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX, STDS LP. SSC PUMP STN-H2		JOB NO. 3921-00 0101
	SUBJECT: 4 wet + 2 Dry Weather Pumps		SHEET 6 OF 9
	DESIGNED: NMP	DATE: 12-11-95	CHECKED / DATE

VALUE PIT NO.2: 14'-0 X 18'-10 X 8'-8 Walls 1'-0" thick

Grating FRP Wt. = 25 psf
Live Load = 150 psf
w = 175 psf

Support beam:

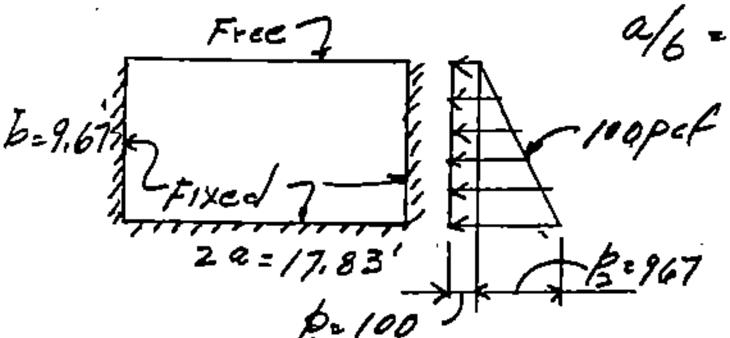
$w = 175\left(\frac{4.33+2.25}{2}\right) = 575$ plf
Bm wt = 25
600 plf.

$l = 16'\text{-}10''$
$M = 0.6 \times 16.83^2/8 = 21.2^{\prime k}$
$V = 0.6 \times 8.42 = 5.05^{k}$ → W8X24 $l_n = 16.83'$
$W = 10.1^{k}$ $M_R = 33.5^{\prime k}$

215e w/ 2-3/4"φ single 3/8" ℞ Conn. w/ 5/16 weld
R = 8.2k

$\Delta = \frac{0.89 \times 10.1}{19} = 0.47'' = \frac{1}{426}$

End Wall: Ref: 2/5 Bureau of Reclamation, EM No.27.



$a/b = \frac{17.83}{2 \times 9.67} = 0.92 \approx 1.00$

$p_1 b = 1.0$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4$.

$M_x^- = 0.2613 \times 9.4 + 0.0644 \times 90.4 = 8.3^{k/ft}$ $M_u = 14.1^{\prime k/ft}$
$M_x^+ = 0.1008 \times 9.4 + 0.0276 \times 90.4 = 3.4$ $= 5.9^{k/ft}$
$M_y^- = 0.2043 \times 9.4 + 0.0845 \times 90.4 = 9.6$ $= 16.3$
$M_y^+ = 0.0243 \times 9.4 + 0.0159 \times 90.4 = 1.7$ $= 2.8$

$t = 12''$ $d_{V_y} = 9.5''$ $F_V = 0.09$
$d_{H_x} = 8.5''$ $F_H = 0.07$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON TX STDS LP, SSC Pump Stn, HZ	JOB NO. 3921-00 0101
	SUBJECT: 4 Wet + 2 Dry Weather Pumps	SHEET 7 of 9
	DESIGNED: NMP / DATE: 12-14-95 / CHECKED:	DATE:

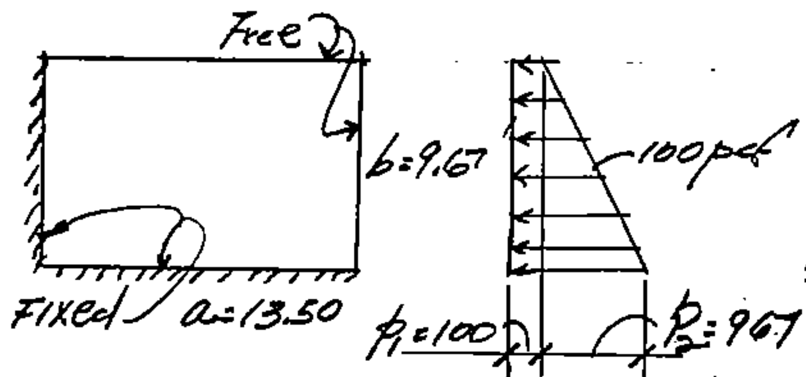
$K_{mx}^- = 201.$ $\rho = 0.0039$ $A_s^- = 0.0039 \times 12'' \times 8.5'' = 0.40\,in^2/ft$ #5@6"H

$K_{mx}^+ = 84.$ $\rho_{min} = 0.0018$ $A_s = 0.0018 \times 12 \times 12 = 0.26$ #5@12"HEF

$K_{my}^- = 181.$ $\rho = 0.0035$ $A_s = 0.0035 \times 12 \times 9.5 = 0.40$ #5@6 DWL

$K_{my}^+ = 31.$ $\rho_{min} = 0.0018$ $= 0.26$ #5@12VEF

Pit Side walls: $a/b = 13.5/9.67 = 1.4 \doteq 1.00$



$p_1 b = 1.0$
$p_1 b^2 = 9.4$
$p_2 b = 9.4$
$p_2 b^2 = 90.4$

$M_x^- = 0.2949 \times 9.4 + 0.0662 \times 90.4 = 8.8\,k/ft$ $M_u = 14.9\,k/ft$
$M_x^+ = 0.0324 \times 9.4 + 0.0077 \times 90.4 = 1.0$ $= 1.7\,k/ft$
$M_y^- = 0.2949 \times 9.4 + 0.1157 \times 90.4 = 13.2$ $= 22.5$
$M_y^+ = 0.0324 \times 9.4 + 0.0172 \times 90.4 = 1.9$ $= 3.2$

$K_{nx}^- = 213.$ $\rho = 0.0041$ $A_{sx}^- = 0.42\,in^2$ #5@6@ Corner
$K_{nx}^+ = 24.$ $\rho_{min} = 0.0018$ $A_s = 0.26\,in^2/ft$ #5@12 HEF.
$K_{my}^- = 250$ $\rho = 0.0049$ $A_{sy}^- = 0.56\,in^2/ft$ #5@6 dwls OF.
$K_{my}^+ = 36.$ $\rho_{min} = 0.0018$ $A_s = 0.26\,in^2/ft$ #5@12 VEF.

Buoyancy check:

Dead Loads; Walls: $2 \times 14' \times 8.67' \times 0.150 = 36.4\,k$
$1 \times 16.83 \times 8.67 \times 0.150 = 21.9$
Baseslab: $14 \times 18.83 \times 1.33 \times 0.150 = 52.6$
Soil: $2 \times 1.0 \times 15.0 \times 8.67 \times 0.06 = 15.6$
$1 \times 1.0 \times 18.83 \times 8.67 \times 0.06 = 9.8$
$136.3\,k \downarrow$

Uplift Force $= 18.83 \times 14 \times 10 \times 0.062 = 164.5\,k$

$\Delta W_{DL} = 1.25 \times 164.5 - 136.3 = 69.3\,k$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT Houston, Tx STDS LP SSC Pump Stn- HZ			JOB NO. 3921-00 0101
	SUBJECT 4 Wet + 2 Dry Weather Pumps			SHEET 8 OF 9
	DESIGNED NMP	DATE 12-14-95	CHECKED	DATE

Consider ΔW_{DL} is available from wet well DL.
Shear transfer to wetwell thru two wall brackets

V, per wall $= 69.3/2 = 34.65^{k}$

$V_u = 1.7 \times 34.65 = \underline{58.9^{k}}$ (uplift)

Wall bracket:

assume wet-well wall $t = 2'0$ min.

$X = 13'6$, $2'0$, $0-6$ → $16-0$　　$Y = 9'5 - 0-6 = 8-11$

$l = \sqrt{16^2 + 8.92^2} - 15.50' = 2.82$ ft

$M_u = 58.9 \times 2.82 = 166^{\,1k}$

Ref: PCA, "Simplified Design" shear walls, pg 6-13.

$\phi M_u = \phi [0.5 A_{st} f_y l_w (1 + \frac{P_u}{A_{st} f_y})(1 - \frac{c}{l_w})$

where $P_u = 0$

$A_{st} = \#5 @ 12 = 0.31 \times 2 \times 8' = 4.96\ in^2$

$l_w = 8.67' = 104''$　　$h = 12''$

$\omega = \frac{A_{st}}{l_w h} \times \frac{f_y}{f_c'} = \frac{4.96}{104 \times 12} \times \frac{60}{4} = 0.0596$

$\frac{c}{l_w} = \frac{\omega}{2\omega + 0.85\beta_1}$　　$\beta_1 = .85$ for $f_c' = 4000$

$= \frac{0.0596}{0.1192 + 0.7225} = 0.071$

$\phi M_u = \frac{0.90 \times 0.5 \times 4.96 \times 60 \times 104 \times 0.929}{12} = \underline{1078^{\,1k}} \gg M_u = 166^{\,1k}$

$V_u = 58.9^{k}/8. = \underline{7.37\ k/ft}$ or per $1\phi \times 2'0$ dwl.

$\phi V_c = \underline{24.2\ k/dwl\ (\text{Controls}) > V_u = 7.37^{k}/dwl.}$

(See sht. 3 of

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS LP, 55C Pump Stn HZ	JOB NO: 3921-00 0101
	SUBJECT: 4 Wet + 2 Dry weather Pumps	SHEET: 9 of 9
	DESIGNED: NMP / DATE: 12-14-95 / CHECKED:	DATE:

Consider Combined bending and Shear of dowels:

$M_u = V_u \times a = 0.50'' \times 7.37 = 3.69$ ''k

$f_{s_t} = \dfrac{3.69}{0.7854 \times 0.5^3} = 37.59$ ksi

$f_{s_v} = \dfrac{7.37 \times 60}{27.1} = 16.32$ ksi

$f_s = \sqrt{37.59^2 + 16.32^2} = \underline{40.98 \text{ ksi} < 60 \text{ ksi}}.$

II <u>Shear Capacity of 1"φ × 2'-0 dwl in base slab:</u> @12" c/c.

$\phi V_c = 25.85$ k/dwl.

or $\phi V_c = \phi V_c' C_w C_t C_c$ where $\phi V_c' = 15.2^k$ $d_e = 8''$

$C_w = 1,$ $n_s = 1.$

$C_t = 1.$ $h > 1.3d_e = 10.4''$

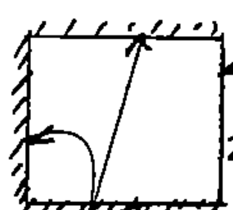
$C_c = 1,$ $d_c > d_e$

$\phi V_c = 15.2$ k/dwl. — controls $\gg V_u = 4.66$ k/ft or dwl.

$\phi V_s = 27.1$ k/dwl.

<u>Base Slab:</u>

$a/b = \dfrac{17.83}{2 \times 13.5} = 0.66$



Hinged

2a = 17.83'

Fixed b = 13.5'

Net Uplift = 10 × 62.4 = 624
− 1.33 × 150 = −200 psf
524 psf ↑

pb = 7.07

$pb^2 = 95.5$

t = 16" d = 16 − 3 − 1 − ½ = 11.5" F = 0.132

$M_x^- = 0.0695 \times 95.5 = 6.64$	$M_u = 11.3$ k/ft	$K_n = 86$	
$M_x^+ = 0.0274 \times 95.5 = 2.62$	$= 4.4$	$= 33$	
$M_y^- = 0.0898 \times 95.5 = 8.58$	$= 14.6$	$= 111$	$\rho = 0.002$
$M_y^+ = 0.0473 \times 95.5 = 4.52$	$= 7.7$	$= 58$	$A_{s\,min} = 0.38$ in²

$V_{hinge\,max} = 0.3874 \times 7.07 = 2.74$ k/ft $V_u = 4.66$ k/ft or #6@12 TEW

#5@8 TEW

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904-00 0101
	SUBJECT: LIFT-STN. W/O VALVE VAULT 4WET & 2 DRY PUMPS			SHEET 19
	DESIGNED: NMP	DATE: 11-4-94	CHECKED: JAM	DATE: 11-8-94

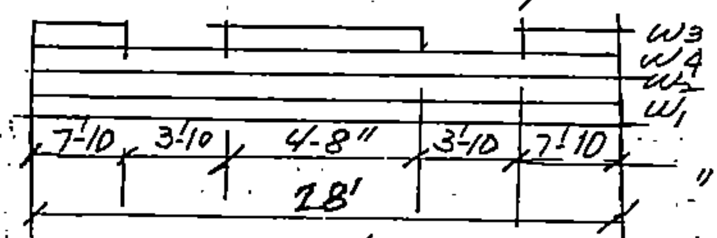
WETWELL: TOP SLAB: (Sht. C34)

Consider 2'-0" thick slab.

Band Beam B1: $b = 3'10" = 46"$
(Between Hatches) $t = 24"$ $d = 21"$, $F = 1.689$.
$\ell = 27'-0"(\pm)$. $\ell_{c/c} = 28'$ (c/c of 1'-0" Brg ea. end)

Loads; DL: $w_1 = 300 \times 3.83' = 1150$ #/ft
$w_2 = 30 \times 4.75' = 150$
$w_3 = 300 \times 2.75' = 825$
LL: $w_4 = 300 \times 8.58' = 2575$

2125 $\times 1.4 = 2.98$ k/ft
$\times 1.7 = 4.38$ k/ft
$\Sigma w_u = 7.36$ k/ft



w_1	$16.1 \times 1.4 = 22.54^k$	22.54^k
w_2	$2.1 \times 1.4 = 2.94$	2.94
w_{3mid}	$1.9 \times 1.4 = 2.69$	2.69
w_{3end}	$6.46 \times 1.4 = 9.04$	9.04
w_4	$36.05 \times 1.7 = 61.29$	61.29
	98.5^k	98.5^k

$M_u = 98.8 \times 13.5' = 1252.8^{'k}$
$- 21.74 \times 6.75' = -146.7$
$- 2.84 \times 6.75 = -19.2$
$- 2.2 \times 1.17' = -2.6$
$- 6.93 \times 9.83' = -68.2$
$- 59.09 \times 6.75 = -398.9$
$617.2^{'k}$
($\ell = 27$)

$V_{ud} = 98.50 - 7.36(0.50 + 1.75)$
$= 81.94^k$

$\phi V_c = 103.9^k$

$K_n = 522$ $\rho = .0107$

$A_s = 10.33 \text{ in}^2$

13 #8 Bott. @ 3½" c/c.
(in 46" width w/ 2½" Side Cover).

$M_u = 98.50 \times 14' = 1379.$
$- 22.54 \times 7' = -158.$
$- 2.94 \times 7' = -20.0$
$- 2.69 \times 1.17 = -3.0$
$- 9.04 \times 10.08' = -91.$
$- 61.29 \times 7' = -429.$
$M_u = 678^{'k}$
$M_{u\,des} = 1.3 M_u = 881^{'k}$

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904-00 0101
SUBJECT: LIFT STN. W/O VALVE VAULT 4 WET + 2 DRY WTR PUMP			SHEET p. 20
DESIGNED: NMP	DATE: 11-4-94	CHECKED: JAM	DATE: 11-8-94

Beam No 2: Between 4 Hatches and Discharge pipes.

$\ell = \sqrt{13.5^2 - 4.81^2} \times 2 = 25.23 + 1.0 = 26.23'$ c/c

$b_2 = 8.44$
-1.00 – 24"ϕ pipe
-4.81
2.63 ft = 31.5" Say 31."

$d = 21"$ $F = 1.139$

Loads: DL: $300 \times 3.63'$ = $1089 \times 1.4 = 1.52$
30 psf $\times 2.52$ = $76 \times 1.4 = 0.11$
LL: $300 \times 6.15'$ = $1845 \times 1.7 = 3.14$

W_{DL+LL} 3010 #/ft $W_{u_{DL+LL}} = 4.77$ k/ft

$M_u = 4.77 \times 26.23^2/8 = 410.$ 'k

$M_{u_{des}} = 1.3 M_u = 533$ 'k

$V_{ud} = 4.77(\frac{26.23}{2} - 0.5 - 1.75) = 51.8$ k

$K_n = 468.$ $\rho = .0095$ $\phi V_c = 0.85 \times 2\sqrt{4000}\, 31 \times 21 = 70.$ k

$A_s = 6.18$ in² 8 #8 @ 3¾" c/c. Bott.

Beam B3: between Hatches:

$b = 1'$-$4\frac{1}{2}"$ $t = 24"$ $d = 20"$

$W = $ DL: $300 \times 1.38'$ = $414 \times 1.4 = 580$
$30 \times 4.50'$ = $135 \times 1.4 = 189.$
LL = $300 \times 5.38'$ = $1614. \times 1.7 = 2744$
2163 W_u 3513. plf.

$\ell = 7'$-$0\frac{1}{2}"$

$M_u = 3.5 \times 7.04^2/8 = 22$ 'k

$M_{u_{des}} = 1.3 M_u = 28$ 'k

$\rho_{min} = 0.0033$ $A_s = 1.04$ in² 2 #8 T & Bott.

$V_u = 12.3$k $< \phi V_c = 35.4$k

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON, TX			JOB NO. 3904.00 0101
SUBJECT: LIFT STN. W/O VALVE VAULT 4 WET + 2DRY WR PUMPS			SHEET 21
DESIGNED: NMP	DATE: 11-7-94	CHECKED: JAM	DATE: 11-8-94

VALVE PADS:

$A = 14'-1''$

$B = 24'-3''$ $\quad m = 0.58$

$W = 12''$ slab $\quad 150psf \times 1.4 = 210$

LL (No truck) $\quad 150psf \times 1.7 = 255$

$300psf \quad w_u = 465psf.$

$M_A = 0.081 \times 0.465 \times 14.04^2 = 7.4\ k/ft \quad K_n = 116$

$M_B = 0.010 \times 0.465 \times 24.25^2 = 2.7\ k/ft$

$V_A = \frac{0.89}{2} \times 0.465 \times 14.04 = 2.91\ k/ft \quad \rho_{min} = 0.0033$

$w_{serv} = 1.87\ k/ft \quad A_s = 0.31\ in^2$

#5@12 Bott EW

#5@8 Top EW.

Gr. Wall:

Loads: Platform $= 1.87\ k/ft$ (max).

wall $= 0.38$

$2.25\ k/ft.$

$b = 1'-0 \quad \frac{P}{Ts} = 2.25ksf < 3.00\ ksf.$

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT CITY OF HOUSTON			JOB NO. 3904-00 0101
	SUBJECT Lift Station w/ Vaults 4 wet + 2 Dry Pumps			SHEET 22
	DESIGNED NMP	DATE 1-19-95	CHECKED	DATE

VALVE VAULT:

Top slab: Loads - 24" slab = 300 psf
Hatch @ 30 psf X 2.5 = 75 } X 1.4 = 525
LL: @ 300 psf, 1 = 300
@ 300 psf X $\frac{2.5}{6.17}$ = 122 } X 1.7 = 717.
W = 797 W_u = 1242

Right Vault:
$L = 27'-9"$ $d = 21"$ $F = 0.441$.
$M_u = 1.24 \times 27.75^2/8 = 119.4$ k/ft
$V_u = 1.24\left(\frac{27.75}{2} - 2.25\right) = 14.4$ k/ft $< \phi V_c = 0.85 \times 2\sqrt{4000} \times 12 \times 21$
$= 27.1$ k/ft
$K_n = 270.7$ $\rho = 0.0053$
$A_s = 1.33$ in²/ft #8@7" Bottom (1.46 in²).
#5@8 Top EW and Transv. to #8. (0.47 in²/ft)

Left Vault:
$l = 17'-10"$
$\rho_{min} = 0.0033$
$A_s = 0.83$ #8@12 Bott. (0.79 in²/ft).

WALLS: See Lift Stn 3 wet + 2 dry Pumps.

BASE SLAB:
Loads: Top slab, DL 300 psf
LL 300 psf
walls: 28.75
20.50
20.50
69.75 ft X 11' X 0.150 = $\frac{115.1^k}{28.75 \times 20.5}$ = 195 psf.

Consider Water table to be up to finish grade. Design Engineer to Verify for 100 yr flood if Critical

h_w = 2'-0"
11-0
2'-6
15'-6"
∴ uplift = 15.5 × 62.4 = 967 psf. ↑

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT City of Houston	JOB NO. 3904-00 0101
	SUBJECT Lift Stn w/Vaults 4 wet + 2 dry Pumps	SHEET 23
	DESIGNED NMP / DATE 1-19-95 / CHECKED	DATE

DL : 24" Top slab = 300 psf
12" walls = 195 "   15" walls → = 244 psf
30" Base slab = 375 "
870 psf ↓

Consider 1'-6" wide ftg outside.

Soil wt = $\frac{(20.5+20.5+31.75)\times1.5\times14.5'\times60\text{ pcf}}{28.75\times20.5} = 161$ psf

ΣDL = 1031 psf ↓   2'-0 wide ftg → = 217 psf

$FS = \frac{1031}{967} = 1.07 < 1.2$

ΣDL required = 1.2 × 967 = 1160 psf

Δ net uplift = 129 psf ↑

I Increase t_{wall} = 15" = 49 psf ↓
Ftg = 2'-0" = 56 psf ↓ } = 105 psf = Δ_{DL}.

✓ Use

II Increase wall thickness, t_w = 16" and ftg to 2'-0"

Walls : 20.50'
20.50'
29.42
70.42 ft × 11. × 1.33 × 0.150 = $\frac{154.9^k}{20.5\times29.42}$ = 257 psf

Soil wt = 20.50
20.50
33.42
74.42 × 14.5 × 2. × 60 pcf = $\frac{129.5^k}{20.5\times29.42}$ = 214 psf

ΣDL = 300 Top slab
257 walls
375 Base slab
214 Backfill
1146 psf ↓ $FS = \frac{1146}{967} = 1.19 \approx 1.20$.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: CITY OF HOUSTON			JOB NO. 3904-00 0101
SUBJECT: Lift Station w/ Vaults 4 wet + 2 dry Pumps			SHEET 24
DESIGNED: NMP	DATE: 1-19-95	CHECKED:	DATE:

Consider Base slab as Two-way slab hinged at all edges.

LL = 300 × 1.7 = 510
Top slab = 300
walls = 257
soil fill = 214
$w = 1071$ psf × 1.4 = 1080

$w_u = 1590$ psf.

$a = 20.50'$
$b = 27.75'$ $m = \frac{20.50}{27.75} = 0.74$

$M^+_{u_A} = 1.59 \times 20.5^2 \times 0.061 = 40.8$ k/ft $K_n = 63$

$M^+_{u_B} = 1.59 \times 27.75^2 \times 0.019 = 23.3$ k/ft

$d = 30'' - 2 - 2 - \frac{1}{2} = 25.5$ (slope) $F = 0.650$

$\rho_{min} = 0.0033$ $A_s = 1.0\,in^2/ft$ #7@7" Top EW.
#5@7" Bott EW.

Smaller Vault:

See 3 wet + 2 dry Pumps Lift Station.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS.	JOB NO. 3921-00 0101
	SUBJECT: CONTROL BUILDING	SHEET 1 OF 5
	DESIGNED: NMP / DATE: 12-19-95 / CHECKED:	DATE:

Roof:

Dead loads: Asphalt shingles = 3 psf
5/8" Plywood Sheathing = 3 psf

Roofslope 5V : 12H ≐ 22.5°

w_{DL} = 7 psf (Horizontal projection)

5/8" Gypsm Ceiling = 3 psf
Trusses @ 16" o/c. Approx wt = 3 psf
Insulation = 2 psf

W_{DL} = 15 psf.

Live load

W_{LL} = 16 psf

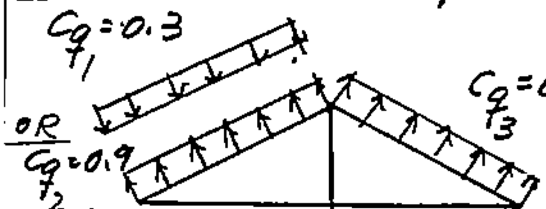
W_{DL+LL} = 31 psf.

Wind load:

Design wind pressure

ROOF:

$p = C_e C_q q_s I$ where $C_e = 1.06$, Exposure C
C_q = See sketches.
q_s = 20.8 psf for 90 MPH
$I = 1.15$



(i) Wind perpendicular to ridge

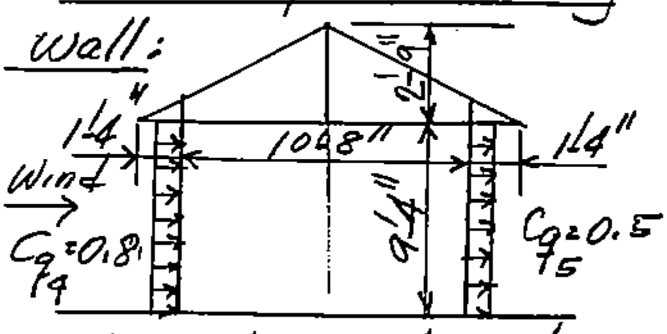
$p = 1.06 \times 20.8 \times 1.15\ C_q$
$= 25.4\ C_q$.

(ii) Wind - parallel to ridge

Roof:

$p_1 = 25.4\ C_{q_1} = 7.62$ say 8 psf
$p_2 = 25.4\ C_{q_2} = 22.86$ 23 psf
$p_3 = 25.4\ C_{q_3} = 17.78$ 18 psf

Wall:



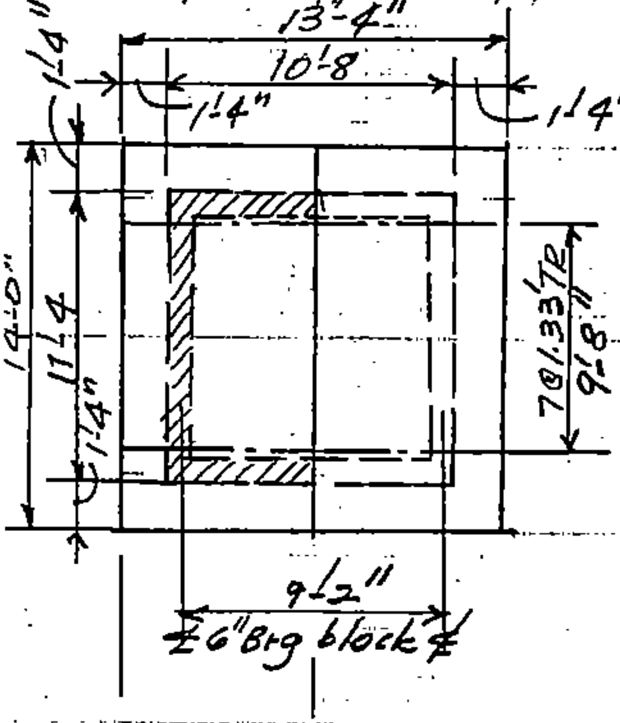
(iii) Wind - any direction

Wall:

$p_4 = 25.4 \times 0.8 = 20.32$ 21 psf
$p_5 = 25.4 \times 0.5 = 12.70$ 13 psf.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS		JOB NO. 3921-00 0101
	SUBJECT: CONTROL BUILDING		SHEET 2 OF 5
	DESIGNED: NMP	DATE: 12-19-95	CHECKED	DATE

Roof trusses spaced at 16" o/c.



Wall Reaction Per truss:

$R_{DL} = 15\,psf \times 1.33 \times \frac{13.33}{2} = 133^{\#}$

$R_{LL} = 16\,psf \times 1.33 \times \frac{13.33}{2} = 142^{\#}$

$R_{WL_1} = 8 \times 1.33 \times \frac{13.33}{2} \times \frac{7.92}{9.17} = 62^{\#}$

$R_{WL_2} = -23 \times 1.33 \times \frac{13.33}{2} \times \frac{7.92}{9.17} = -176^{\#}$

$R_{WL_3} = -18 \times 1.33 \times \frac{13.33}{2} \times \frac{1.25}{9.17} = -22^{\#}$

$R_{DL+LL} = 133 + 142 = 275\,\#.$

$R_{DL+LL+WL} = 275 + 62 - 22 = 315^{\#}$

$R_{DL-WL} = 133 - 176 - 22 = \underline{-65^{\#}}$ uplift

Anchor Truss to 2"x6" wall plate w/ Per Truss Hurricane ties to take 65 lbs uplift and 97 lbs lateral Force.

Wall: Height of wall = h = 9'-4"

Wind load = 21 psf.

$M_{des} = 0.75 \times 21 \times 9.33^2/8 = 171$ ft-lbs/ft $< M_R = 598$

$V_{des} = 0.75 \times 21 \times 9.33/2 = 73$ lbs/ft

$V/truss = 1.33 \times 73 = 97$ lbs

N = axial load

= 275 lbs/Truss

= -65 lbs uplift/Truss.

Neglecting axial load, 6" CMU $f'_{cm} = 1500$ psi

#5@24" Vert Reinf

$M_R = \frac{7175}{12} = 598$ ft-lbs/ft.

NOTE: Continue #5@24" Vert. Reinf. in to bond beam at top of wall.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: HOUSTON, TX STDS			JOB NO: 3921-00 0101
SUBJECT: CONTROL BLDG			SHEET: 3 OF 5
DESIGNED: NMP	DATE: 12-21-95	CHECKED:	DATE:

Wall Top plate: Anchored to masonry w/ 5/8" Dia X 12" Long at 24" c/c.

$M = \frac{65 \times 24}{4} = 390$ in-lbs.

$V = 65/2 = 33$ lbs

2"X6" plate (southern Pine) Select str. $S = \frac{5.50 \times 1.5^2}{6} = 2.06\ in^3$

$f_t = \frac{390}{2.06} = 189$ psi $< F_t = 1200$ psi.

$v = \frac{33 \times 1.5}{8.25} = 6$ psi $< F_v = 95$ psi.

Bond beam:

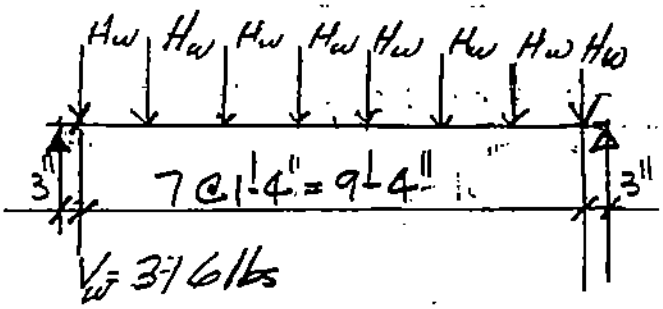
8"x8" w/ 2 #5 bars Cont. w/ 2"X6" Wall plate

$Wt = 0.67 \times 0.67 \times 130$ pcf $= 58$ lbs/ft

OR $1.33 \times 58 = 78$ lbs/Truss > 68 lbs uplift

Lateral load per truss per wall

$H_W = \frac{25.4 \times 9.33 \times 1.33'}{2 \times 2 walls} = 79$ lbs/Truss



$M_W = 316 \times 4.92' = 1555$ ft-lbs
$- 79 (0.67 + 2 + 3.33 + 4.67) = -843$

$M_W = 712$ ft-lbs.

$V_W = 316$ lbs.

2X6 Wall Pl $S = 7.563\ in^3$

$f_t = \frac{712 \times 12}{7.563} = 1130$ psi $< F_t = 1200$

Bond Bm: 2#5 bars in 8"x8" block $= 0.62\ in^2/8"$

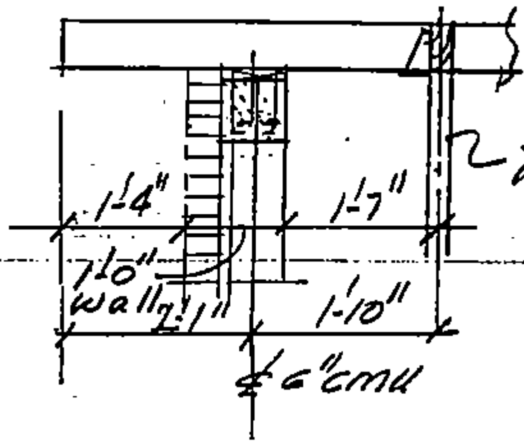
OR $= 0.93\ in^2/ft \approx$ #7 @ 8"

$M_R = 20142$ in-lb/ft

or $M_{R_W} = \frac{20142 \times 0.67}{12 \times 0.75} = 1500$ ft-lbs

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX STDS			JOB NO. 3921-00 0101
	SUBJECT: CONTROL BLDG			SHEET 4 OF 5
	DESIGNED: NMP	DATE: 12-21-95	CHECKED	DATE

Look-Outs :



Uplift on look-out

$w_w = 1.33' \times 23 = -31$ lbs/ft ↑

$w_{DL} = 1.33 \times 15 = 20$ lbs/ft ↓

$w_{LL} = 1.33 \times 16 = 22$ lbs/ft ↓

$M_{(DL+LL)_1} = 42 \times 2.08^2/2 = 91$ ft-lbs

2"×4", $S = 3.063$ in^3

$f_t = \dfrac{91 \times 12}{3.063} = 356$ psi $< F_t = 1200$

$\Delta V_2 = \dfrac{91}{1.83} = \pm 50$ lbs ↑

$V_2 = \dfrac{42 \times 1.83}{2} = 38$ lbs ↓

$V_{2L} = 38 + 50 = 58$ lbs

$V_{2R} = 38 - 50 = \underline{-12 \text{ lbs}}$ ↑ uplift at Truss

$w_{DL+WL} = -31 + 20 = -11$ lb/ft. $V_1 = 23$ lbs ↑

$M_{W_1} = 11 \times 2.08^2/2 = 24$ '#.

$\Delta V_2 = \dfrac{24}{1.83} = \pm 13$ lbs

$V_2 = \dfrac{11 \times 1.83}{2} = -10$ lbs

$V_{2L} = -10 - 13 = -23$ lbs ↑

$V_{2R} = -10 + 13 = 3$ lbs

max. uplift at Wall $= V_1 + V_{2L} = \underline{-46 \text{ lbs}}$ ↑

Provide Hurricane strap between 2"×4" Look-Outs and 2"×6" wall plate. Anchor wall plate w/ 5/8"φ @ 2'-0" into CMU Bond beam on top of wall.

CTE ENGINEERS CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.	PROJECT: HOUSTON, TX, STDS			JOB NO. 3921-00 010
	SUBJECT: CONTROL BLDG			SHEET 5 OF 5
	DESIGNED: NMP	DATE: 12-21-95	CHECKED:	DATE:

End Wall:

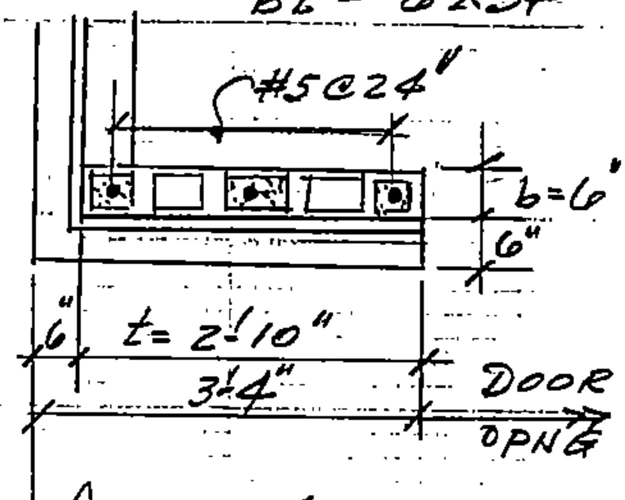
Consider wall with door opening

H_{Top} = 316 lbs wind load on 3'-4" wall length. 40"-9" = 31"

$M_w = 316 \times 9.33' = 2948$ ft-lbs

$V_w = 316$ lbs.

$bt = 6" \times 34"$ d = 31"



$A_s = 0.31 in^2$ 1#5 Ea Face

$h/t = \frac{9.33}{2.83} = 3.3 > 1.5$ acts as Flexural Element.

Allow Shear, $F_v = \sqrt{1500} = 35$ psi

$f_v = \frac{316}{0.8 \times 5.62 \times 34} = 2$ psi $< \frac{1}{2} F_v = 17$ psi

Assume Axial load, P=0.

$f_{bt} = 25$ psi

$M_R = f_{bt} S = \frac{25 \times 6 \times 34^2}{12 \times 6} = \underline{2408} > 0.75 M_w = \underline{2211}$ ft-lbs.

or $M_R = F_s A_s jd = \frac{20000 \times 0.31 \times 0.8 \times 31}{12} = \underline{12813}$ ft-lbs

Wall load at Gr. Floor Level:

Roof: w = 315/1.33 = 237 lbs/ft

wall (40+2+40) × 9.33 = 765

Gr. Floor 8" slab = 100 psf

LL = 250 "

350 psf × 2.0' = 700 lbs/ft

Gr. wall 1' × 2.0' × 150 pcf = 300 lbs/ft

W = 2002 lbs/ft

Allow. Soil bearing press = 2000 psf b = 1'-0" Ftg reqd.

CTE ENGINEERS
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

PROJECT: Houston, Tx, STDS			JOB NO. 3921-00 0101
SUBJECT: CONTROL BLDG			SHEET 6 of 6
DESIGNED: NMP	DATE: 1-22-96	CHECKED	DATE

Roof sheathing:

5/8" Exterior grade Plywood on trusses @ 16" o/c.
Consider 8d ($l = 2\frac{1}{2}$") common nails.
min. penetration = 2.50 - 0.63" = 1.87"
UBC Table 25G V = 78 lbs/nail. w/ $1\frac{1}{2}$" pen.
25H T = 41 lb/nail/1" pen.

Allowable V = 78 × 1.87/1.50 = 97 lbs
Allowable T = 41 × 1.87 = 76 lbs.
max uplift = 23 psf × 1.33 = 31 lbs/ft along truss
max shear = $\frac{14 \times 21}{2 \times 6.66'} \times 2.75 \times \frac{7.21}{6.66}$ = 66 lb/ft along truss

provide 8d common nail at 8" o/c along truss. (16" o/c shear and 16" Tension nails)
Tallowable = $\frac{76}{1.33}$ = 57 lbs/ft > 31 lbs/ft actual
Vallowable = $\frac{97}{1.33}$ = 73 lbs/ft > 66 lbs/ft actual

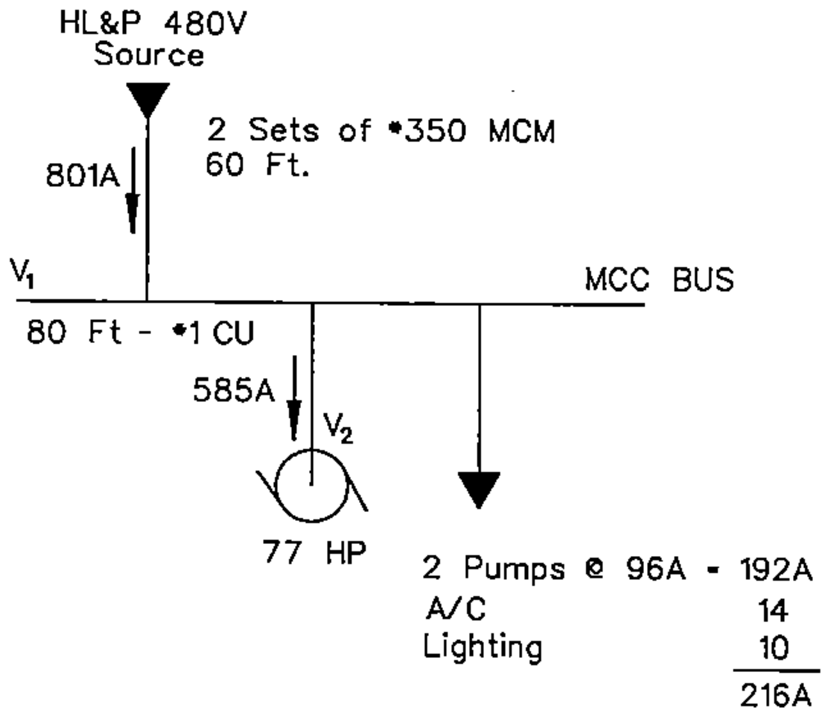
PLYWOOD NAILING SCHEDULE	
BOUNDARY NAILING	= 8d ● 4" O.C.
PANEL EDGES WITHIN 5'-0" OF ROOF EDGE ● EA. GABLE	= 8d ● 4" O.C.
OTHER PANEL EDGES & FIELD NAILING	= 8d ● 6" O.C.
ALL NAILS SHALL BE GALVANIZED COMMON NAILS	

APPENDIX C

TYPICAL ELECTRICAL DESIGN CALCULATION EXAMPLES

VOLTAGE DROP CALCULATIONS

1. Assume starting pump 3 with 2 pumps at full load and all auxiliaries on. (Pump 4 on standby).
2. Use published full load amps and starting inrush amps at 460V on 480V system.
3. Power factor = 0.95.



$$V_1 = 480 - \left(\frac{801}{2}\right)\left(\frac{60\ \text{Ft}}{1000}\right)\left(0.101\right)$$

$$V_1 = 477.6\text{V} \qquad V_{D1} = \frac{(480-477.6)}{480} = 0.50\%$$

$$V_2 = V_1 - \frac{(585)(80\ \text{Ft})}{1000}\left(0.308\right)$$

$$V_2 = 477.6 - 14.4$$

$$V_2 = 463.2 \qquad V_{D2} = \frac{(480-463.2)}{480} = 3.50\%$$

POWER FACTOR CORRECTION CALCULATIONS

PUMP DATA

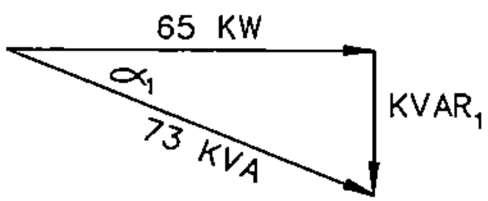
Rated Output	-	77 HP (57 KW)
Rated Input	-	92A @ 460V (65 KW)
Published PF @ 100%	-	0.89
Published PF @ 50%	-	0.82

100% LOAD

Input KVA $= (92)(0.46)\sqrt{3} = 73$ KVA

Input PF $= \dfrac{65 \text{ KW}}{73 \text{ KVA}} = \underline{\underline{0.89}}$ - checks with published value

Input Conditions:



$KVAR_1 = \sqrt{73^2 - 65^2}$

$KVAR_1 = \underline{\underline{33.2}}$

Check:

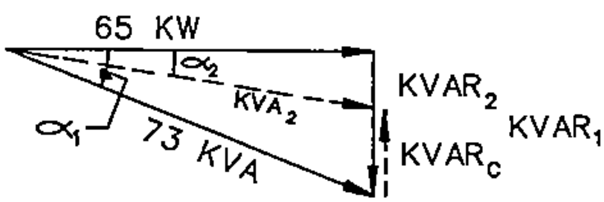
$\alpha_1 = \cos^{-1}(0.89) = 27.1°$

$KVAR_1 = [\sin(\alpha_1)](73 \text{ KVA})$

$= (0.456)(73)$

$= \underline{\underline{33.3}}$

To Correct PF To 0.95 LAG:



$PF = \dfrac{KW}{KVA_2}$

$KVA_2 = \dfrac{KW}{PF} = \dfrac{65}{0.95}$

$= 68.4$ KVA

$KVAR_2 = \sqrt{68.4^2 - 65^2}$

$KVAR_2 = 21.3$

Check:

$\alpha_2 = \cos^{-1}(0.95) = 18.2°$

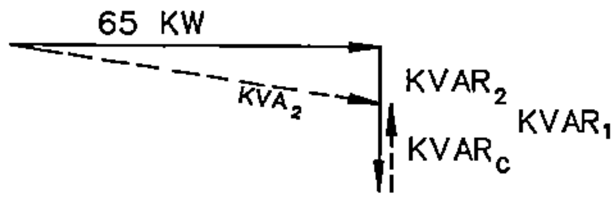
$KVAR_2 = [\sin(18.2)](68.4)$

$= \underline{\underline{21.3}}$

$$KVAR_c = KVAR_1 - KVAR_2$$
$$= 33.3 - 21.3$$
$$= \underline{\underline{12\ KVAR}}$$

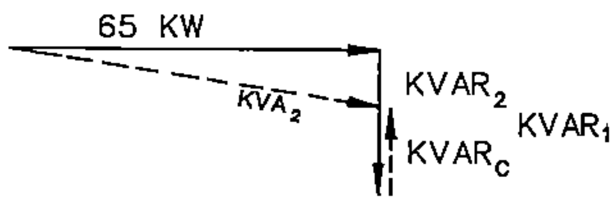
Standard Commercial Sizes --> <u>10 KVAR or 15 KVAR</u>

Using <u>10 KVAR</u> Correction:



$$KVAR_2 = KVAR_1 - KVAR_c$$
$$= 33.3 - 10$$
$$= 23.3\ KVAR$$
$$KVA_2 = \sqrt{65^2 + 23.3^2}$$
$$= 69\ KVA$$
$$PF = \frac{65}{69} = 0.942$$

Using <u>15 KVAR</u> Correction:

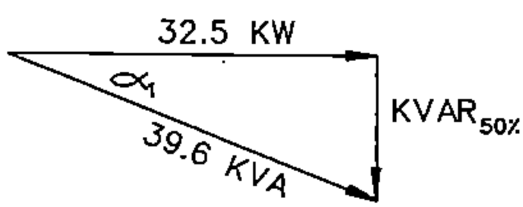


$$KVAR_2 = KVAR_1 - KVAR_c$$
$$= 33.3 - 15$$
$$= 18.3\ KVAR$$
$$KVA_2 = \sqrt{65^2 + 18.3^2}$$
$$= 67.5\ KVA$$
$$PF = \frac{65}{67.5} = 0.96$$

<u>50% LOAD</u>

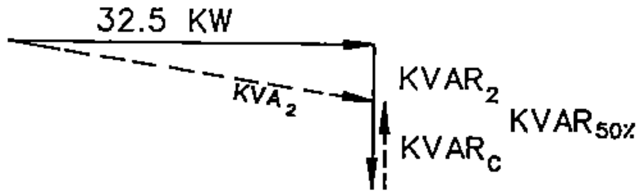
100% Input KW = 65KW -->
50% Input KW = 65 KW/2 = 32.5 KW

50% PF = 0.82 --> $KVA_{50\%} = \frac{32.5}{0.82} = 39.6\ KVA$



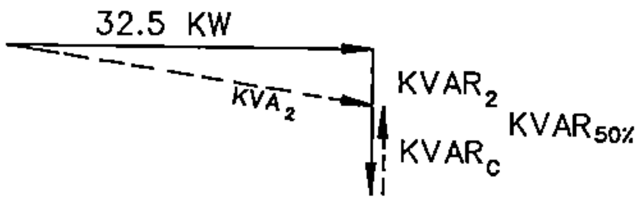
$$KVAR_{50\%} = \sqrt{39.6^2 - 32.5^2}$$
$$= 22.6\ KVAR$$

Using <u>10 KVAR</u> Correction:



$$KVAR_2 = KVAR_{50\%} - KVAR_C$$
$$= 22.6 - 10$$
$$= 12.6 \text{ KVAR}$$
$$KVA_2 = \sqrt{32.5^2 + 12.6^2}$$
$$= 34.8 \text{ KVA}$$
$$PF = \frac{32.5}{34.8} = 0.933$$

Using <u>15 KVAR</u> Correction:



$$KVAR_2 = KVAR_{50\%} - KVAR_C$$
$$= 22.6 - 15$$
$$= 7.6 \text{ KVAR}$$
$$KVA_2 = \sqrt{32.5^2 + 7.6^2}$$
$$= 33.4 \text{ KVA}$$
$$PF = \frac{32.5}{33.4} = 0.97$$

<u>USE 15 KVAR CAPACITORS</u>

USING 15 KVAR CAPACITORS:

$$I_C = \frac{15 \text{ KVAR}}{(0.48)\sqrt{3}} = 18A$$

Per NEC 460-8:

Minimum capacitor conductor ampacities --> of

135% of I_C or

33% of motor circuit conductors

I_C X 135% = (18)(1.35) = 24.3

Motor conductor ampacity (#1) = 130A

130A /3 = 43.3A - Minimum

Use #8 CU capacitor conductors

LOAD CALCULATIONS

MOTOR CONTROL CENTER			
CIRCUIT	DESCRIPTION	HP / KVA	FLA
1	MAIN BREAKER	---	
2	PUMP NO. 1	75 HP	96
3	PUMP NO. 2	75 HP	96
4	PUMP NO. 3	75 HP	96
5	PUMP NO. 4	75 HP	96
6	AIR CONDITIONER	10 HP	14
7	LIGHTING TRANSFORMER	5 KVA	10
TOTAL			408

LIGHTING PANEL			
CIRCUIT	DESCRIPTION	WATTS	
1	CONTROL POWER	200	
2	MCC HEATER	150	
3	PLC		250
4	AIR COMPRESOR		500
5	LIGHTS	170	
6	SPARE	500	
7	BUILDING RECPTACLES		360
8	SPARE		500
9	SPARE	500	
10	SPARE	500	
11	SPACE		500
12	SPACE		500
TOTAL WATTS		4630 WATTS	
SERVICE VOLTAGE		240 VOLTS	
TOTAL AMPERES		19 AMPS	

FAULT CALCULATIONS

STATION TYPE 4 PUMPS @ 75 HP (KVA)

SERVICE VOLTAGE	480	BASE KV	0.48
TRANSFORMER KVA	500	USED AS BASE KVA	
XFORMER Z – POLE MTD	0.02		
XFORMER Z – PAD MTD	0.03		

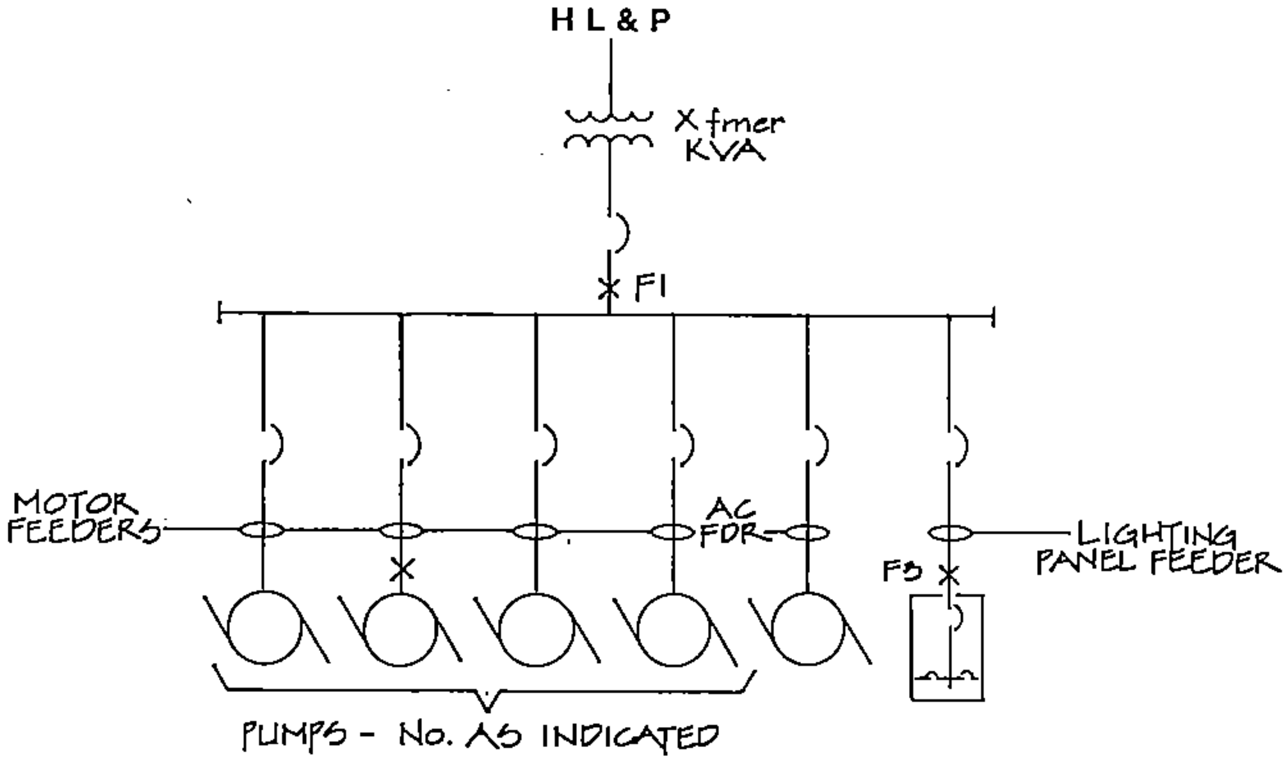
FEEDERS –	NO.		AWG	LENGTH	Z tot	Z pu
MAIN	3	–	350	100	0.002063	0.0045
PUMPS	1	–	1/0	50	0.0067	0.0145
AIR CONDITIONING	1	–	6	20	0.00988	0.0214
LIGHTING PANEL	1	–	6	20	0.00988	0.0214

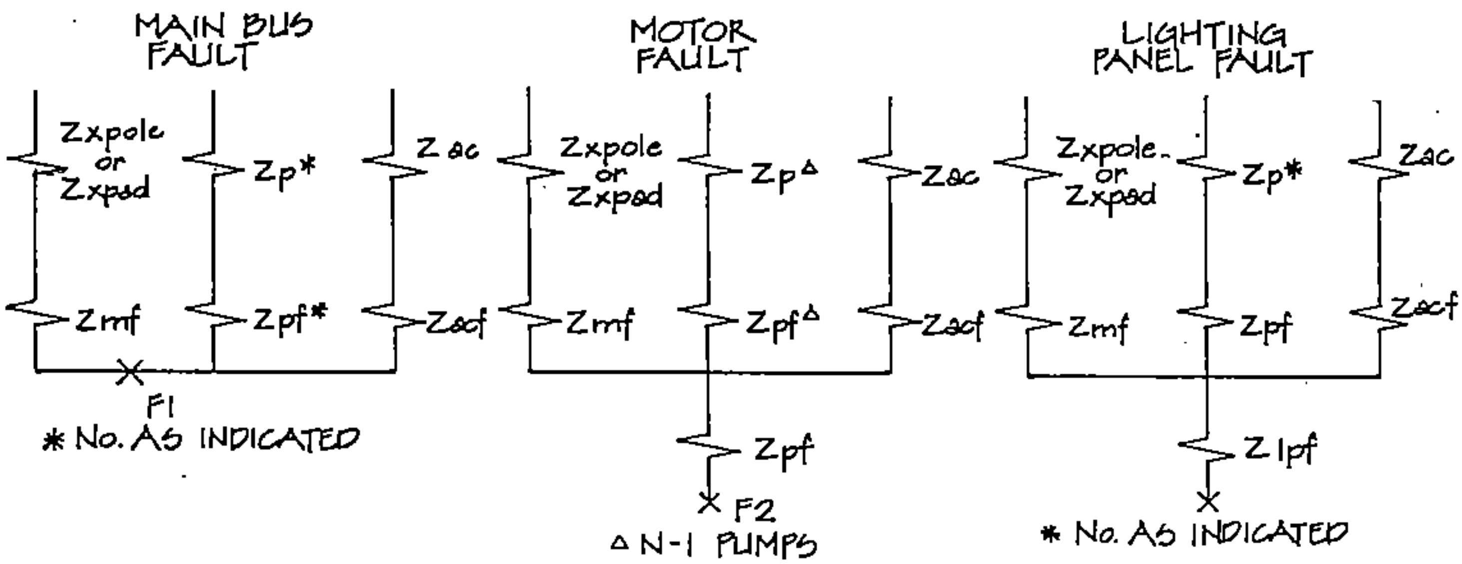
LOADS	KVA	Z pu
PUMPS	75	1.6667
AIR CONDITIONING	10	12.5000

EQUIVALENT Z pu	POLE MTD	PAD MTD
XFORMER & FEEDER	0.0245	0.0345
ALL PUMPS	2.3792	
N–1 PUMPS	1.7844	
AIR CONDITIONING	12.5214	

	POLE MTD		PAD MTD	
FAULT CURRENTS	Z tot	I sc	Z tot	I sc
MAIN BUS	0.0242	24870	0.0339	17744
AT MOTOR	0.0386	15564	0.0483	12458
AT LIGHTING PANEL	0.0456	13182	0.0553	10869

SHORT CIRCUIT CALCULATIONS





MOTOR DATA

Rated Output Power HP(Kw)	Ø	Vnom	Full Load Amps	Starting Amps Surge/LR	Locked Rotor KVA	NEC Code Letter	Rated Input Power (Kw)	Poles/RPM
32 (24)	3	460 575	42 34	234/164 187/131	131	D	27	8/875
6 Pole 60 (45)	3	460 575	72 58	445/287 356/230	228	C	51	6/1165
8 Pole 60 (45)	3	460 575	81 65	380/243 304/194	193	B	52	8/875
77 (57)	3	460 575	92 74	585/375 468/300	298	C	65	6/1170
88 (66)	3	460 575	108 86	590/445 472/356	354	D	73	4/1770
120 (90)	3	460 575	140 112	1030/765 824/612	609	F	100	4/1775

Pump Motor HP	EFFICIENCY			POWER FACTOR		
	100% Load	75% Load	50% Load	100% Load	75% Load	50% Load
32	87.5	86.9	84.2	0.82	0.78	0.70
60(6 Pole)	88.5	88.5	86.8	0.89	0.87	0.82
60(8 Pole)	87.5	88.0	86.5	0.82	0.79	0.71
77	87.7	87.5	86.8	0.89	0.87	0.82
88	90.0	90.0	88.0	0.85	0.82	0.75
120	90.0	90.0	88.5	0.89	0.87	0.81

CABLE DATA

HP x Volts	Max. Length ft.	Gauge	Nominal Dia.	Conductors (in one cable)
32 x 460 32 x 575	630 970	#4/3-2-1-GC #4/3-2-1-GC	33.8mm (1.33") 33.8mm (1.33")	(3) #4 AWG (PWR) (2) #10 AWG (CTRL) (1) #6 AWG (GND) (1) #10 AWG (G.C.)
60 x 460 60 x 575	240 340	#4/3-2-1-GC #4/3-2-1-GC	33.8mm (1.33") 33.8mm (1.33")	
77 x 460 77 x 575	560 840	#1/3-2-1-GC #1/3-2-1-GC	41.7mm (1.64") 41.7mm (1.64")	(3) #1 AWG (PWR) (2) #10 AWG (CTRL) (1) #1 AWG (GND) (1) #8 AWG (G.C.)
88 x 460 88 x 575	480 720	#1/3-2-1-GC #1/3-2-1-GC	41.7mm (1.64") 41.7mm (1.64")	
120 x 460 120 x 575	475 745	#0/3-0-2-GC	42.0mm (1.65")	(3) #0 AWG (PWR) (2) #5 AWG (GND) (1) #5 AWG (G.C.)
120	Pilot Cable	#14/7	17.8mm (0.70")	(7) #14 AWG